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THE EFFECTS OF ONTOGENETIC CHANGE ON PSYCHO-MOTOR ABILITIES AND ADAPTATION TO RESPONSE ERRORS

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In the midst of winter
I finally learned
That there was in me
An invincible summer

— Albert Camus

This dissertation is dedicated to
three persons whom I greatly admire:
to my mother, Mary Iris Teaffe,
who taught me to endure with dignity;
to my father, the late John Berchmans Teaffe,
who taught me to fight for what I believed in;
and to my grandmother, the late Helena Mary McKenna,
who taught me the value of compassion and humour.
To all of you I extend my thanks, my love,
and my prayers.

You have my respect,

M.

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ABSTRACT

This study differs from previous investigations into the effects of ontogenetic change on motor performance in several ways. It encorporated equal numbers of males and females, and equal numbers of subjects in all of the six "demi-decade" age groups ranging from 55 to 84 years. It categorized subjects into cardiovascular behavioral profiles, and maintained strict standards pertaining to cardiovascular health and visual acuity. This experiment also employed the use of a subject-paced pursuit tracking task facilitating the measurement of performance speed and accuracy variables concurrently. A repeated measures design was employed to identify changes in performance with practice. Subjects also completed the Jenkins' Activity Survey which classified their possible predisposition to coronary heart disease. Based on the results of this survey, all of the subjects over the age of 75 years were found to have a Type B behavioral profile. Therefore, all of the comparisons of cardiovascular behavioral profile, i.e., Type A vs. Type B, were restricted to those subjects aged 55 to 74 years.

The data for response speed measures including total response time, correct reaction time, and non-overshoot movement time, indicated that younger subjects were generally significantly faster than were older subjects. Males were significantly faster than were females, particularly in the the first block of trials. The cardiovascular behavioral profiles did not differ in performance speed significantly. The data for the performance accuracy measures, error rate and overshoot rate,

indicated that generally, younger subjects were significantly more accurate than were older subjects, although this age-accuracy relationship was erratic. The difference between males and females on accuracy measures was not significant. Similarly, the cardiovascular behavior profiles did not differ significantly in their accuracy rates. Finally, the data indicated that the increase in reaction times following a response error were not statistically significant between younger and older subjects; between males and females; or between Type A and Type B cardiovascular behavioral profile subjects.

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CHAPTER ONE

Introduction

In general, motor performance theory attempts to explain how skilled performers utilize available information in perceiving, deciding upon, and organizing an action in accordance with the ~~demands~~ placed on them by the environment (Schmidt, 1982). An overview of the literature suggests that if this processing is efficient and accurate then the resultant movement should be coordinated with the specific demands of the task. If on the other hand, the processing is faulty then the resulting action(s) may be in error. Hence, studying the incidence of, and the type of errors made by an individual, in this case an aging individual, provides a means of examining processing efficiency in motor performance (Marteniuk, 1976; Massaro, 1975).

Rationale

Error reduction is acknowledged as being one of the main characteristics of the learning process. Errors are important in that learning how to anticipate, avoid, and/or respond to errors is a key factor when attempting to improve the level of performance. In the past the focus of studies evaluating the effects of aging on psychomotor performance has been on performance decrements (i.e., the slowing with age) rather than on how seniors respond to these changes (i.e., the compensations made with age). Numerous experiments and reviews have identified a myriad of physical and psychological adaptations that are incurred with age. However,

> "Coming to terms with these problems while still being able to engage in substitute activities and retain a high sense of life satisfaction, is the major demand made on the aging. Trying to understand these processes and to learn how to intervene in order to slow down or reverse negative outcomes is a major demand made on the gerontologist." (Kalish, 1975, p.33).

Herrick (1983) in his study of interbehavioral perspectives on aging concluded that gerontological psychologists have through their uncritical use of "...medieval conceptions of behavior directly contributed to the negative stereotypes of elderly persons found in our society" (Herrick, 1983, p.95). This "scientific ageism" has, "...both given rise to and perpetuated notions regarding the supposed behavioral incompetence of the elderly" (Herrick, 1983, p.95).

According to Price, Fein, and Feinberg (1980) who studied the neuropsychological assessment of cognitive function in the elderly, emphasis should be shifted away from describing "deficits" in the aged (grouped en-masse) when young adult performances are the implicit standard of comparison. Instead a realistic and qualified representative evaluation of cognitive functions is needed.

Statement of the Problem

People of all ages make mistakes. To err is still human and "People make errors as a byproduct of the same information processing mechanisms that produce their creativity and flexibility" (Norman, 1980, p.106). Research has shown this propensity to commit errors does change as a function of age, gender, and cardiovascular behavior profile. The research questions to be answered involve exploring the relative contributions age, gender, and cardiovascular behavioral profile make to one's ability to respond to, and align a pursuit pointer with an illuminated target; and to compensatory actions taken following a response error. For example, was speed sacrificed to regain accuracy?

Purpose of the Study

This study will attempt to achieve a better understanding of the relative contributions age, cardiovascular behavioral profile and gender make to psychomotor abilities by encorporating the following constraints into its design. Several notions pertaining to improving research in the area of aging have evolved from the literature reviewed. These suggestions propose to facilitate the accurate assessment of psychomotor abilities through the use of a subject-paced task (Craik,1977; Gaylord & Marsh,1975; Michenbaum,1972), utilizing a repeated measures design (Lehman & Kral,1968; Murrell,1970), comparing adults to adults (Price, Fein & Feinberg,1980), representing both males and females in equal numbers (Botwinick & Storandt,1967; Botwinick &

Thompson,1966; Noble et al., 1964), and screening for cardiovascular status in subject selection (Abrahams & Birren,1973; Bortner & Rosenman,1967; and Speith,1965).

Contributions of the Study

By the year 2030, an estimated 50 percent of the population will be middle-aged or older (Butler & Lewis, 1982). With improved health care, new discoveries in medicine and a persistent low birth rate the population of older persons may increase even more dramatically. Regarding the proposed study, it should be noted that efficient motor performance is fundamental to the quality of everyday life and to the ability to maintain an independent living style, which is a critical issue for seniors.

It is important therefore, that research be directed towards the older population and the aging phenomena, with the purpose of ensuring functional as well as chronological longevity. In so doing perhaps the quality of life and independence experienced during the middle and later years of life may be enhanced. As mankind's understanding of how motor skills breakdown with age improves so then may one's ability to teach seniors how to modify and improve the motor skills so crucial to enjoying an independent lifestyle.

It must be recognized that the age of onset, and the severity of and the reaction to psychomotor deficits vary from person to person. By acknowledging these individual differences, myths and stereotypes are then less likely to distort one's perceptions of the aging process. This process, which often seems to be one of inevitable physical and psychological decline, might more realistically (and optimistically) be seen as a process of adaptation to specific changes.

In addition, Speith (1965) has tentatively suggested that coronary heart disease individuals (described as having a Type A behavior) may make more psychomotor errors than their healthy contemporaries (described as having a Type B behavior). Bortner and Rosenman (1967) reported that this errorful slowing in performance may be evident prior to the overt manifestation of the physical dysfunction. Consequently, if decrements in motor performance are associated with aging, and with disease, then accurate information on the extent of, and the nature of these decrements may prove valuable when counselling the elderly regarding possible consequent changes in their life style, particularly if illness is involved. Health care professionals may one day use the relative functional motor ability of their clients to prescribe rational meaningful supplementary activities, such as those involving cognitive decision-making and/or physical fitness, to enhance or maintain their client's well-being. In motor behavior terms, understanding how information is processed and behavior regulated may facilitate continued performance (Stelmach, 1982a).

Definition of Terms

-- Before this discussion on human performance continues perhaps several of the terms which are to be employed should be defined.

Information

Events such as words, movements, sounds or pictures (or as in the case of the present study, the illumination of a target light) convey particular information. The more unfamiliar or unpredictable the event is, the more potential information it holds, such as its location or acceleration.

Information Processing

In executing a perceptual-motor skill, a number of central nervous system operations precede the actual movement. Each of these operations manipulates information in some manner and consequently takes time. Information processing here refers to the use of information to result in movement.

Information Transmission

When an individual uses information from the event and the environment in order to produce a movement, information is said to have been transmitted. In other words, the environmental information acts as "input" to the central nervous system operations underlying movement. This movement is then the "output".

Perceptual-Motor Skill

For the purpose of this paper, a perceptual-motor skill will refer to those activities involved in manipulating the body (or parts thereof) in order to accomplish a specific objective. Similar to a cognitive skill, emphasis will be placed on the central nervous system operations preceeding the movement.

Perceptual-Motor Learning

While perceptual-motor performance is the present level at which an individual executes a skill, learning is concerned with his or her improvement in a facet of the skill for example, the speed or the accuracy with which the information is processed.

Motor Commands

Once the plan of action has been selected (specifying the values of the various parameters of the movement with respect to the environmental demands) it must be coordinated. The effector mechanism organizes the necessary sequencing of nervous impulses, and sends these commands (orders) to the muscles to produce the desired movement.

Movement Execution and Control

Once these patterns of nervous impulses have been directed to the muscles, movement execution follows. At this point these muscles are not only under the auspices of the initial motor commands, but they are also, shortly, subject to the influence of feedback.

CHAPTER TWO

SURVEY OF RELATED LITERATURE

Perceptual motor performance is said to be based upon the interaction of three variables. The first of these concerns the demands of the specific task, especially the demands performers make upon themselves for standards of achievement. Hence, the initial discussion in this chapter will be of the attitudes society has of the elderly, and how these societal mores and the attitudes the elderly have of themselves, and of their situation, effect their performance on psychomotor assessments. Following this presentation, the issue of task complexity will be reviewed through the observed age-related declines in reaction and movement time.

The second of the three variables, and the next section of the review, focusses on the mental and physical capacities of the performer. The purpose of this section will be to review the age-related changes specific to information processing abilities (including sensory reception), with regard to their relative implications for the production, and monitoring of motor responses. Welford's (1958) model of information processing (see Figure 1) will be used as a general framework for this discussion because, "...it presents a unified view of human perceptual-motor performance, [and] can be used to study all perceptual-motor activity, not only from theoretical and research viewpoints but also from an applied viewpoint" (Marteniuk, 1976, p.17). This model views the perceiver as an active rather than a passive recipient of environmental information. It views the transformation of this information as serially linked complex researchable operations. Each mechanism will be discussed relative to its function and adaptations made to aging. Interwoven with this review of mental and physical capacities, the third of the three variables, the voluntary cognitive adaptations, will be assessed. This variable, and section, concentrate on the strategies adopted to offset limitations, such as failing visual acuity or slowing in the rate of information processing, and to accentuate strengths, such as their wealth of experience, and expertise. In addition to the review of normal adaptations to the aging process, the effects of cardiovascular status, and of physical activity will also be summarized, because each has been reported to be a powerful influence respectively exacerbating and retarding ontogenetic changes.

Attitudes Expressed Towards the Elderly

Socially, culturally and historically the elderly are regarded as behaviorally incompetent. And true to the form of a self-fulfilling prophecy even the elderly have come to believe in these sometimes reckless overgeneralizations. For example, Milligan et al. (1981) examined learning and reaction time performance in older veterans as a function of their attitudes towards themselves and the elderly in general. Old (55-70 years) and young (20-35 years) hospitalized veterans were tested on serial learning tasks with exposure times of either 4 or 10 seconds, and also on simple and choice reaction time tasks.

Their results showed that older subjects with faster psychomotor performances have "... significantly more positive attitudes toward older people and significantly better life satisfaction scores..." (Milligan et al., 1981, p.164) than do other older veterans. It was suggested that both the younger and older veterans, "...view an older person as less effective, less acceptable, and less autonomous than they do a younger person" (Milligan et al., 1981, p.160). These perceptions concur with the earlier findings of Rosencranz and McNevin (1969) and Bennett and Eckman (1973) on performance and attitude. The attitude seems to be exhibited in the elderly's fear of failure being greater than their need to achieve. Similarly the elderly do not wish to appear foolish or incompetent should they make an error or an inappropriate response and so they avoid taking the risk in the first place (Kalish, 1975). While this is not true for all elderly people it seems to be true for most. Perhaps their use of compensatory strategies comes only as a result of the perceived physiological changes and the "stigma" attached to these decrements. Perhaps the changes and the strategies merely exacerbate one another. Prior to examining these strategic compromises, the physiological changes related to psychomotor performance will be discussed.

The Effects of Aging on Reaction Time and Movement Time

Slowness of behavior is perhaps one of the most obvious changes perceived in the elderly. Not only is this slowing apparent in their motor responses, but it is also evident in their highest decision-making neural processes of the central nervous system. In reviewing the evidence on caution (which could potentially produce this generalized slowing) Botwinick (1978, p.125) concluded, "While there is controversy whether or not the trade-off of speed for accuracy, and the ommission error for the commission error is volitional in nature, there is little doubt that older people do not tend to risk being wrong for the sake of being right or fast". Cautiousness may then be interpreted as a, "...disinclination to respond quickly because of the importance attached to making a mistake" (Birren, Woods & Williams, 1980, p.302). That is, "...the human is able to adjust his tracking performance according to his criteria for weighting the error" (Bosser, 1982, p.392). But what of the peripheral decrements associated with aging, are they not instrumental in defining the limitations around which the individual expresses his or her potential? The answer to this question is affirmative, but perhaps not to the extent that one might think they are.

The Mechanics of Information Processing

In general, human performance theory attempts to study how skilled performers utilize information in perceiving, deciding on and executing an action relative to the demands placed on them by the environment (Schmidt, 1982). If the processing of available information is efficient and accurate in light of man's ability to sense, attend to, process, store, and transmit the information then the resultant movement should be coordinated to the demands of the task. If the processing is faulty, then in all likelihood so too is the response.

Three major mechanisms are said to characterize the information processing system: perceptual, central and effector (Welford,1958). In turn each of these mechanisms is comprised of several sub-processes (often referred to as stages), all of which virtually simultaneously contribute to the production of the perceptual-motor response. The central tenet of this information processing model is that before one actually performs an activity, a number of mental operations must first be negotiated. This "thinking before acting" notion is by no means new. A great deal of the credit must be accorded to Donders (1969) for his auspicious discussions on the grey area between perception and response.

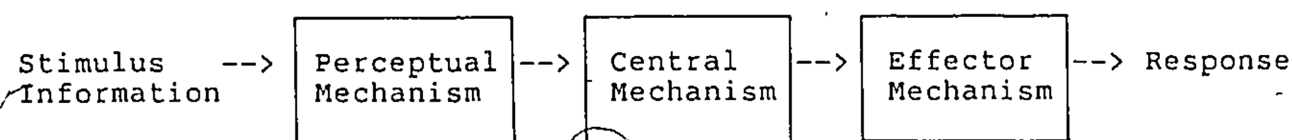

Figure 1 Schematic Drawing of Welford's (1958) Information Processing Model

According to Massaro (1975) there are four major assumptions to this model. Each of these will be briefly outlined here:

(1) The stages of processing exist and are identifiable.
(2) The stages are operations which require time to complete. Complex tasks requiring additional operations will also require additional time to process.
(3) Each stage operates only on the information made available to it.
(4) Each stage manipulates this information in some way making it available to the next stage of processing.

It ought to be remembered that, "...the most basic assumption of the information processing framework is that all mental operations take time" (Stelmach, 1982a, p.70). Reaction time, or the period from the presentation of the stimulus to the initiation of the response has been divided into distinct intervals of definite duration. Reaction time reflects the period of time required for the transmission of the signal/message from the activated nerve receptors to the brain and in turn for the brain to activate the appropriate muscle fibre units to initiate the response. In keeping with the assumptions of the model the duration of this reaction time is thought to be proportional to the number of mental operations that take place between the stimulus onset and the eventual response.

Over the years reaction time has been shown to be affected by the sense modality stimulated, stimulus intensity, the amount of information contained in the stimulus, and the number of response options to be selected from. To illustrate, reaction time to a visual stimulus has been estimated to be approximately 180 msec, to an auditory stimulus 160 msec, to a tactile stimulus 140 msec, and to kinesthetic stimuli 120 msec (Kerr, 1982) while other factors were held constant.

Sternberg (1969) reported that stimulus intensity directly affects detection while stimulus-response compatability affects response selection. This latter variable reflects the complexity of the relationship between the stimulus and the response. While decreases in either the stimulus intensity or in the stimulus-response compatability have resulted in increased reaction times, this seems especially true for older adults (Massaro, 1975; Pierson & Montoye, 1958; Welford, 1978)

Stage One, the Perceptual Mechanism

For most motor skills the efficient processing of all sources of information, be it from perception, memory, or feedback, is the key ingredient to the execution of a skilled performance (Schmidt, 1982). As such performance is based upon an accurate and efficient moment to moment assessment of an (often changing) environment and task at hand. Generally, it is perception that furnishes the information necessary for that ongoing analysis. Perception represents the first step in the processing of motor skill information, thereby profoundly influencing the entire central processing system. Perception is distinct from mere sensation in that it is an active, conscious interpretation and integration of incoming information/stimuli that provides the basis for decisions and actions (such as the execution of a skill), and for learning (Marteniuk, 1976; Massaro, 1975; Schmidt, 1982).

The accuracy of one's perceptions is affected by age-related changes at both the basic sensory and the higher cognitive voluntary levels. Two important age-related structural changes that limit visual acuity include: (1) a decrease in the diameter of the pupil; and (2) thickening and yellowing of the crystalline lens which diffuses and distorts the image projected on the retina. These changes in the lens also filter out green, blue and violet colours at the shorter wave length of the spectrum (Hoyer & Plude, 1980; McPherson, 1983). The structure of the retina is such that as one moves from the fovea to the periphery the number of cones decreases and the number of rods increases. Fine grain patterns are better received by the fovea while moving stimuli or signals of low intensity may be dealt with more quickly if they fall on the periphery where the concentration of rods is greater (Brebner & Welford, 1980). It might then be plausible that this reduction in pupil diameter with age (Hoyer & Plude, 1980) would narrow the image projected on the retina. By concentrating the image on the fovea away from the periphery and its higher density of rods, the functional ability to detect movement attenuates with age. As a result of the distortion of the image and the limited ability of the retina to detect movement, more time and effort must be taken for accurate image identification with age. A higher incidence of traffic accidents in the elderly was attributed to the confusion between the red, green and amber signal lights (Panek, Barrett, Sterns & Alexander, 1977). A possible insensitivity to red lights in general (brake lights in particular) may also have resulted in inappropriate driving behavior.

Both of the aforementioned age-related structural changes of the eye limit the amount and the quality of light reaching the retina (Hoyer & Plude, 1980; Kalish, 1975; McPherson, 1983). Bearing this in mind it is easy to understand why, "...recent evidence suggests that older persons are at a disadvantage in tasks requiring the processing of brief information" (Walsh,1976, p.555). It also seems fitting to suggest that visual acuity of subjects be standardized before assessing the processing efficiency of an elderly population.

As a means of testing central processing abilities masking paradigms have been utilized. When two stimuli are flashed or presented in rapid succession their visual traces may interact to the exclusion of one. The first stimulus may obscure traces of the second (forward masking) or the second stimulus may obscure the first (backward masking). "In either case the interference results because the visual system takes some amount of time to clear or to recover from the stimulation. The longer this signal processing takes, the greater is the opportunity for masking to occur" (Hoyer & Plude, 1980, p.229). This opportunity seems to present itself more often to the elderly (Panek et al., 1977).

Similarly, Walsh (1976) using a central masking paradigm found a 31 percent increase in the time required by an older person to escape masking over and above the time required by a younger person. The response to a second signal may be slowed due to involuntary continued attention to the feedback from the previous movement to the exclusion of immediate attention to new signals (Rabbitt & Rogers, 1965; Welford, 1978).

Kline and Szafran (1975) concluded from their study of perceptual processing time that there is with increasing age a corresponding significant increase in the time required to completely process a single perceptual event. In turn, this reduces the total number of perceptual events that an aging visual system can handle per unit time, even though the stages of processing are virtually the same (Giambra & Arenberg, 1980; Hoyer & Plude, 1980; Lee & Pollack, 1978; McPherson, 1983). However, when the time interval between the pair of stimuli increases, the older persons outperform the younger (possibly now overconfident and/or bored) subjects. It is, therefore, necessary that experimenters provide an adequate preparatory interval in order to safeguard against biasing the task to the detriment of the older participant.

To continue with the discussion of age-related changes in visual efficiency the following studies have been cited. The sequential integration of stimuli presented in succession is processed more slowly by older adults than by younger adults, perhaps because the older adults are more susceptible to the effects of luminance summation (glare) and contrast reduction

(Kalish, 1975; Panek et al., 1977). The notion of stimulus persistence is somewhat controversial with respect to its effect upon processing rate. "Stimulus persistence refers to the possibility that the neural representation of a stimulus persists for some time after offset of the physical energy impinging on the receptor surface" (Haber & Standing, 1969, p.43). Hence, because of the extended refractory period required by aging neurons the rate of information processing may be slowed.

Birren and Botwinick (1955) studied age-related changes in nerve conduction along pathways of differing lengths. Release responses by the finger, jaw and foot of the subjects to an auditory stimuli were measured. The differences in response times were insignificant. The investigators suggested that it is unlikely that the speed of transmission (conduction) is a sufficient explanation for slowed psychomotor performance with advancing age, although it may be of greater importance when taken in conjunction with other neurological changes of a more central origin. These results lend credence to the opinion expressed by Welford (1980, p.331) that, "Slowing of processes in the sense organs and falling speed of nerve conduction with age account for what is almost always a negligible proportion of the whole reaction time..." decrement.

Older persons have been known to be disproportionately distracted by the number of irrelevant cues they have to deal with. To investigate the existence of age decrement in the ability to ignore irrelevant information Rabbitt (1977) used a visual search paradigm. Generally, as the number of non-target items in the display increases, the more difficult it is to detect a target within that display. This phenomenon has been termed the "display-size effect". The magnitude of the display-size effect is reflected in the subject's inability to ignore irrelevant items while searching for relevant ones. In Rabbitt's (1977) study this inability was greater among the older than the younger adults, indicating that the older subjects were disproportionately slowed as the number of distractions increased.

To further examine this age and irrelevancy issue Farkas and Hoyer (1980) employed a selective filtering task which required card sorting based on the target-figure orientation. Their experiment illustrated that older subjects were significantly slower than younger subjects when required to discriminate and sort target stimuli in the presence of similarly oriented irrelevant stimuli. When these irrelevant stimuli (non-target items) were of contrasting orientation to the target stimuli, and the location of the target stimuli remained constant between cards, no significant difference in card sorting times for the younger, middle-aged and older groups was found. This finding supported the author's original contention that the slowing observed among older persons was not merely due to an increased difficulty in filtering irrelevant information, but rather to an increased difficulty with the perceptual organization of target stimuli when in the presence of similar non-target stimuli. Rather than proposing that older people remember less because they process slower, "... they may divert their processing resources to concurrent processing demands and thus never complete the operations necessary for efficient encoding and retrieval of information from secondary memory" (Hartley, Harker & Walsh, 1980, p.243). In some of the earlier studies older subjects became frustrated when they failed to keep up with the ongoing pace of the task and as a result quit altogether (Kirchner, 1958). To offset this problem in the present study, there will be no danger of subjects falling behind because a subject-paced tracking task will be employed to assess their monitoring ability.

Simon and Pourabagher (1978) found that there was little difference in the subsequent processing of information by young (mean age=20 years) and old subjects (mean age=73 years) other than the time involved. The older subjects took significantly longer than the younger subjects and the primary locus of their slowing seemed to be in stimulus reception and identification of the stimulus encoding stage. Hence, "When a task is not heavily loaded with mental operations (eg. simple RT), age differences tend to be minimal" (Simon & Pourabagher, 1978, p.559). Herrick (1983) has suggested that the problems encountered by older subjects may extend beyond initial stimulus encoding. According to Herrick, the mechanisms responsible for the registration and retrieval of encoded information may also be impaired.

Once the signal (a neural impulse resulting from sensory stimulation) reaches the brain it has to be distinguished from the background of random neural activity in order to be detected. Distinguishing this signal from background noise is fundamental to subsequent processing of information.

"Most, perhaps all slowing of performance with age can be attributed either directly or indirectly to a fall of signal to noise ratio in the brain" (Welford, 1980, p.333). Neural noise is thought to result from random background activity or by irregularities in the action of the cells carrying the signals. This theory, however plausible, is very difficult to validate because no known neural mechanism has been identified to explain this phenomenon.

In keeping with this notion of relevancy, it has been argued that the amount of information that can be processed at any given time is limited. A myriad of environmental information confronts the sensory organs each and every moment. Sounds, movements in and around the individual, the temperature and degree of sunlight all impress upon the individuals receptors. As a result, when faced with performing, one is forced to attend only to that information which is meaningful or relevant to the successful completion of the task. This selective attention provides a means of focussing on that which is relevant while filtering out that which is not, so that only significant information occupies the immediate attention of the perceptual mechanism. Research in this area seems to have adopted two distinct views of attention allocation, that of capacity, and structure. Capacity models (Kahneman,1973; Moray,1970) are based on processing systems with a limited pool of attention. All mental processes are assumed to require attention. While the processing of information can be allocated to any number of "input channels", the overall attention demands must remain within the capacity of the system. If the demands of two or more simultaneous operations exceed the system's limit, then decrements in performance ensue.

In opposition to this view, structural models (Broadbent,1958; Keele, 1973) maintain that detection and recognition may operate without attention, but later stages such as decision and response selection may not. Only one operation demanding attention may be processed at a time. Confusion starts when two or more mental operations compete for attention, regardless of their overall demands. It is possible, however, to simultaneously process two operations if one of them does not require attention. The question then arises, can these two tasks be performed simultaneously by the elderly with the same precision and efficiency, without delays and/or loss of accuracy, as if the tasks were executed independently. The elderly have been shown to decline in selective attentional ability (Craik, 1977; Rose, 1982). Consequently, the quantity of relevant information to which attention could be allocated at any given time decreases with age.

While decrements in attentional capacity with age appear on novel tasks they do not on familiar ones, probably because the rate at which automaticity is acquired is equivalent between younger and older adults (Hoyer & Plude, 1980; Rose, 1982).

To examine the relationship between selective attention and automobile accident involvement in adults Mihal and Barrett (1976) subjected 75 randomly selected drivers (aged 45 to 64 years) from a utility company to a dichotic listening task. The drivers were divided into groups according to the number of reported automobile accidents that they had incurred in the previous five years. These groups were then compared on mean number of errors scored on the dichotic listening task.

Accident-free drivers recorded a mean score of 25 errors (S.D.=13.64); drivers in the 1-accident group recorded a mean score of 45.20 errors (S.D.=37.12) and drivers in the 2-or-more-accident group recorded a mean score of 47.59 errors (S.D.=38.93) on the same task. These findings seem to indicate that those drivers who exhibit greater selective attention abilities are less likely to be involved in car accidents. In terms germane to the proposed study, poor selective attention may predipose individuals to make errors in judgement. However, it is difficult to generalize these findings to an elderly population for several reasons. The first reason pertains to the age of the subjects, none of whom were over the age of 65 years. Secondly, neither feedback reflecting the correctness of the response, nor the oppotunity to improve responses on subsequent trials was accorded subjects. Had a repeated measures design been used, a different picture may have evolved regarding selective attention and errors. Finally, no reference was made ensuring that precautions were taken to standardize the familiarity of the task. While the results of this study sound promising, their acceptance must be guarded.

From the literature reviewed so far there is strong evidence to suggest that with age, decrements appear in all of the sub-processes of the perceptual mechanism. This dysfunction is more apparent in novel tasks requiring a concerted effort to perform because, "The impact of attentional deficits increases when the memory load is large and requires deeper and more elaborate encoding", (Hartley, Harker & Walsh, 1980, p.244). There is evidence of diminution in the sensory acuity/detection subprocesses (Hoyer & Plude, 1980; Kalish, 1975; McPherson, 1983) and also in the registration and retrieval of encoded information (Hartley, Harker & Walsh, 1980; Herrick, 1983; Simon & Pourabagher, 1978). In addition, Rabbitt's (1964) work on card sorting illustrates an inability on the part of the older adult to ignore irrelevant stimuli in favour of relevant items possibly due to poorer perceptual organization (Farkas & Hoyer,1980). The fact that deterioration occurs in the perceptual mechanism leaves the individual vulnerable to conceivably innumerable motor performance errors. If the system is slowed the amount of information that can be processed per unit time is reduced, and it is possible that in some instances not enough information will have been gathered before the individual is called upon to respond. If the characteristics of the situation have been mis-perceived errors are then likely to ensue.

Stage Two, the Central Mechanism

In keeping with the information processing model, once the distinctive features of the situation have been perceived, they are then transmitted to the central processing mechanism.

The subprocesses assumed to reside within the central mechanism are the decision, memory, and translation stages. The decision stage involves the selection of an appropriate response based upon the demands of the task and any past experience the performer has had with this particular or a similar situation. Welford (1978) suggested that the main slowing with age is not in the execution of the movement but rather in the central processes involved in the selection of the movements to make. Precise signal detection plays a vital role in supplying information on which response selection is based. The card sorting task of Rabbitt (1964) illustrates this point. Rabbitt found that although the increase in time taken with age was directly related to the number of stimuli calling for any one response, it was much less than the increase associated with a rise in the number of responses to be made, "...implying that the perceptual factors were less important than those concerned with choice of response" (Welford, 1980, p.345).

According to Massaro's (1975) second major assumption of information processing concerning the intricacy of the stimulus, the central organization of sensory activity (information) is performed more rapidly when fewer decoding processes are required.(For clarrification of these assumptions refer to page

13 of this text.) In short, signal simplicity facilitates rapid processing of information and, in turn, response execution.

There have been several reviews of the motor performance literature as it pertains to ontogenetic changes but probably the most prominent are those by Welford (1977, 1979, 1980). While these reviews are all-encompassing the principal tenet deals with the issue of central processing limitations regarding decision-making. This is not to deny the existence of, or underestimate decrements in the peripheral sensory system. Rather it is to underline the fact that while age-related changes in the peripheral sensory mechanisms may impair the processing of feedback (Landahl & Birren, 1959; Szafran, 1951), in most sensorimotor tasks the signals are much too clear to independently cause the observed "retardation" in performance (Singleton,1954; Welford, 1977).

In support of this contention, Welford (1979) noted that (a) these decrements occur regardless of the sensory system assessed, (b) the changes in simple reaction time are greater than those seen in reflex activity (Hugen et al., 1960), and (c) the slowness is not due to a lack of motivation in the elderly (Clay, 1957; Weiss, 1965).

In a meta-analysis of the field of motor learning, the slowing in simple reaction time from ages 20 to 70 years has been estimated to be 26 percent (Welford, 1977) while the slowing in choice reaction time ranges from 27 to 51 percent depending upon the certainty of the target location (Birren, Riegel & Morrison, 1962).

In the study by Birren, Riegel and Morrison (1962) subjects were shown a two tier apparatus with ten lights along the top row and ten buttons below (i.e., 1 button below each light). When the response was to press the button directly below the illuminated light (the compatible task) the 60-80 year group took 27 percent longer than the 18-33 year group. When the response was to press the numbered button which corresponded to the position of the light in the row, but not directly above the button, (the incompatible task) the older subjects took 51 percent longer than the younger subjects.

In a similar but more difficult task, Welford (1977) used a 12 choice task. The reaction times for compatible choices rose by 13 percent between the 25-34 year group and the 65-72 year group. When the responses for the compatible task had a spatial transposition imposed (that is, the lights were placed three feet across the table from the buttons) the increase in reaction time across groups was 25 percent. When incompatible responses (called spatial translations by Welford) were required a 56 percent increase in reaction time between the age groups was found. Further, when both a symbolic translation and a spatial transposition had to be overcome the increase in reaction time between the two age groups was 299 percent. Truly the integration of information from a decidedly more complex task takes markedly longer for an older adult (Brebner & Welford, 1980). Of importance to the present study, just as reaction times escalated when spatial or symbolic translations were involved so too did the error rate (Welford, 1980).

It seems that when a prepared response is made to the presentation of a pre-determined signal, and presumably, little decision-making is required, there is little change in reaction time as a function of aging, at least until the 70's (Welford, 1978). Older subjects require more time to process available information in order to make a decision confidently, and therefore, are at a disadvantage, or are disproportionately slowed in performing complex tasks requiring extensive decision-making (Welford, 1978). Consequently, if time restrictions imposed on performance limit the accuracy of their information processing, the elderly are liable to generate more errors.

In some studies employing complex tasks, performances of the older subjects differ significantly from not only that of younger subjects, but also from one-another (Gaylord & Marsh, 1975). Fozard et al.'s (1976) study into the effects of age and the frequency of stimulus repetitions on choice reaction time yielded similar findings regarding the lack of homogeneity in performances of older subjects. The absolute differences in mean reaction time to stimulus alterations and repetitions were found to increase with age. In order to study age-related differences in between- an within-subject variability in reaction time, cumulative frequency distributions of the reponses to alternating ~~and~~ to repeating stimuli were analysed. "The results of the analysis indicated were that both inter- and intra-subject variability of performances was greater in the oldest group than in the others" (Fozard et al., 1976, p.563).

Relative to the variability of adult performance, according to previous research reaction times to a visual stimulus vary indirectly with one's confidence level (Vickers, 1979) and with one's positive attitudes about self-competence and life satisfaction (Milligan et al., 1981). Perceived self-competence and confidence are then integrally involved in adult performance. Mowbray (1960) suggested that as the total number of signals increases, the "key" signal to which a response has to be made becomes relatively less frequent. Consequently, reactions are likely to be slower because of temporal uncertainty. If this temporal uncertainty is compounded by the unstable sense of adequacy associated with aging, then a disproportionate slowing in adult reaction times to complex tasks will result. Interestingly, researchers seem to disagree on the extent to which the elderly are capable of using probability to improve their processing efficiency. Gottsdanker (1982) found that subjects between the ages of 21 and 78 years were able to benefit from advance probability information to shorten their reaction times, and prepare to depress a key on cue. On the other hand, Rabbitt (1968) suggested that it is not clear whether older subjects make relatively effective use of the information that one stimulus is more likely to be presented, or whether it is easier for them to repeat a response just made on a repetitive versus alternating stimulus presentation design. This arguement has been disputed by the later research of Waugh et al. (1973) and Fozard et al. (1976). Both of these latter studies found older subjects to be just as sensitive to changes in the alternating-repetitive sequence of stimulus presentation as were younger subjects. That no difference between the average number of errors made by the younger and older groups was also found is of importance to the present study.

As with reaction times, the effect of aging on movement time appears to vary with the nature of the task. When responses involve substantial movements, these changes tend to be more systematic and to be greater than those for corresponding reaction times. Pierson and Montoye (1958) devised an experiment where in response to a light signal subjects had to raise their hand from a microswitch and thrust it forward with a full arm extension over a distance of about 12 inches in a single unaimed movement. In examining the responses of subjects ranging in ages from 10 to 20 years the movement time for this task decreased by 63 percent across the 10 year span. In going from 20 to 60 years the movement time increased by 74 percent while the reaction time increased 27 percent. When gross motor movements were involved, movement time increases with age were two to three times greater than reaction time increases.

The performance of simple repetitive tapping movements between two targets show little change with age (Morikyo & Nishioka, 1966; Welford, Norris & Shock, 1969). Conversely, more elaborate fine motor movements such as writing digits or tracing a complex pattern show substantial (60-120 percent) changes with age (Birren & Botwinick, 1951; Rose, 1982).

It must be understood that with age there are physiological changes such as a reduction in the overall number of muscle units, changes in the metabolism of those units remaining, and increased thresholds for the neural excitation of the muscle fibers (Welford, 1979). Collectively, these changes result in a 15 to 35 percent decrease (from the 20's to the 60's) in the maximum instantaneous force that can be exerted by a wide range of muscle groups, and in grip strength. During exhaustive or intensive muscular work the time to the onset of fatique is significanty shortened. Although joints do become "stiffer" with age, the limitations imposed by this reduction in flexibility are thought to be relatively minor. According to Welford (1977) muscular limitations probably play an important role in rapid unaimed movements, while limitations in the central nervous system are more crucial to the execution of aimed movements. This would partially explain the observed difficulty older adults have with complex tasks. This difficulty is even more pronounced when performance is slowed to maximize accuracy and minimize errors.

Larish and Stelmach (1982) suggested that when seniors have fewer errors coupled with heightened reaction times they become consciously more deliberate in identifying the response and executing the movement to be made, and if necessary corrected. This issue of pre-meditated movement rekindles the discussion on the origin(s) of the observed age-related performance decrements. Is the elderly adult slow because he or she, "...must be slow, wants to be slow, or has a set to be slow" (Birren, Woods &

Williams, 1980, p.302)? As has been illustrated throughout this review there is evidence to support any one or a combinaton of these restraints.

To briefly summarize, it seems clear that while physiological declines are associated with age there is also an attitudinal change which emphasizes the older adult's preference for accuracy over speed (Botwinick, 1978). There seems to be a conscious decision on the part of the elderly to avoid the risk of making mistakes (Biren, Woods & Williams, 1980). It may be that the thought of making such a "costly mistake" biases the central decision-making processes and therefore strongly influences the overall processing of information. Tasks requiring involved processing and/or intricate movement execution disproportionately slow the elderly (Birren & Botwinick, 1951; Brebner & Welford, 1980). While age-related decrements in the peripheral sensory mechanisms and in biomechanical function impair motor performance, the major constraints on movement production stem from central processing limitations regarding decsion-making (Welford, 1979).

Compensatory Strategies Employed by the Elderly

The exhibition of motor performance is often assessed in terms of one's "skill", that is, the proficiency with which one deploys the appropriate physical and mental capacities to meet the specific demands of the task (Schmidt, 1982). Sometimes during adulthood certain compensatory strategies are employed to make up for possible declines in physiological capacities, such as in muscular strength or in visual acuity, enabling the person to continue to achieve his or her desired goals. There is considerable evidence to suggest that older people tend to focus more on what they are doing (Welford, 1958), are more cautious in their execution of the task (Botwinick, 1966, 1969; Calhoun & Hutchison, 1981; Craik, 1969; Welford, 1980) and all things being equal, will sacrifice speed for accuracy (Botwinick & Thompson, 1966, 1967; Calhoun & Hutchison, 1981; McPherson, 1983; Welford, 1958).

This cautiousness in task execution in old age is no longer thought of as being due to rigidity or to conservativeness but rather that it "...is a learned behavior in reaction to neurobiological slowness" (McPherson, 1983, p.177). The hesitancy is a "...generalized tendency to respond slowly or not at all because of the possible consequences of a mistake" (McPherson, 1983, p.178). To this Herrick (1983) added, "...lack of confidence and anxiety are additional noncognitive factors suggested by some as contributing to increased response rates among the elderly" (Herrick, 1983, p.101). McPherson's (1983) findings support those of Calhoun and Hutchison (1981) who in examining decision-making practices in old age, found that when given the opportunity to avoid making decisions on the Choice Dilemna Questionnaire (CDQ), the elderly do, even under the "no risk" conditions. Moreover, elderly individuals appear to become more conservative and cautious in their decisions when the outcome is directed at young people. It seems that the elderly take even hypothetical responsibility and its supposed consequences quite seriously.

As was just mentioned, the elderly tend to focus more on what they are doing (Welford, 1958). While using more time to consider outcomes and to respond in an attempt to improve performance, often leads to fewer errors, the elderly do not always choose appropriate strategies for problem solving. Canestrari (1963) reported that young and old subjects generate fewer errors when both the inspection and anticipation intervals are relatively long (3.0 sec.) than when the intervals are short (1.5 sec.). Additionally, the older group benefited much more than did the younger group from the slower pace. By frequently increasing the anticipation interval (but not the inspection interval), the older group effectively allocated the time available to respond but seldom took more time to actually analyse the appropriateness of the response.

Another study into the utility of strategies employed by the adult was that by Kleinman and Bradzinsky (1978), who examined haptic exploration in 54 young, middle-aged and elderly adults. Forty-five of the subjects were women. During each of 15 fifteen trials (three practice and twelve test) subjects had to identify (through touching and manipulation) which of the "alternative" objects that they could feel with their left hand matched the "standard" object they could manipulate with their right hand. The number of "options" from which to select was two, three, or four. The task was a self-paced blind examination in that the subjects could not see the objects to be compared because of a screen positioned in front of them.

As the number of alternatives (and therefore task uncertainty) rose both the young and middle-aged groups significantly increased their exploration time but the old group did so only moderately. The young groups' performance dropped, while both the middle-aged and old groups actually improved slightly when the number of alternatives rose from two to three. However, when the fourth alternative was added the old groups' performance also became less accurate. This was a self-paced examination, so the time restriction factor was not responsible for the errors generated by older subjects. Instead, it seemed that the old group employed different strategies on this task than did the young and middle-aged groups, as assessed by impartial observers. The elderly tried less frequently to determine the number of alternatives from which to choose; they also did not attempt to establish the shape of the standard in the early stages of the scanning problem. "Furthermore, elderly adults did not examine all the comparison stimuli in a problem as often as young and middle-aged adults" (Kleinman & Brodzinsky, 1978, p.524). These researchers concluded that the elderly seem to choose more often those search strategies that appear to be relatively ineffective in matching accuracy. Younger and middle-aged adults seemed to use search strategies that are much more conducive to matching-to-standard success. It is somewhat difficult to generalize these findings to the aging population at large because over 83 percent of the subjects used were female. There is a definite need to balance gender in subject populations before such a generalization can be made.

In a somewhat different matching-to-standard comparison Coyne et al. (1978) examined adult age differences in reflection-impulsivity on a modified Matching Familiar Figures Test (MFF). The performances of the twenty older subjects (61-87 years) were compared to those of the younger subjects (18-27 years). Each subject looked at the alternatives presented and determined which of these best matched the standard. The standard and alternatives were presented simultaneously much like a "split-screen" approach only on paper instead of a screen. In the twenty-four sets of pictures presented, twelve of these sets had the correct standard present in the group of alternatives, twelve sets did not. While both age groups committed significantly fewer errors when the original standard was actually present, the older subjects had a higher error rate than the younger subjects in both test conditions (i.e., where the standard was present, or not present). The younger subjects took significantly longer to respond in the condition where the standard was present than they did when it was not present, and yet they were still significantly more accurate than their older counterparts. The older subjects were consistent in their response latencies in each of the conditions regardless of reflective-impulsive style.

Activation theory, which pertains to the level of arousal, postulates the inverted-U-hypothesis. This hypothesis describes the close relationship that exists between performance and arousal levels, such that with an increase in the arousal level there is an associated increase in performance up to a maximum level, after which any further increase in arousal results in a decrease in performance. According to Arenberg & Robertson-Tchabo (1977), frustrating experiences encountered in the testing situations may be pushing the elderly "over the top" so to speak, that is, beyond the limits of performance (such as pace) with which they feel comfortable.

Generally, older people tend to pace themselves better than do younger people, perhaps in an effort to combat this increased arousal. They also tend to work harder and usually check and recheck their work more often than do younger people (Welford, 1977). In situations where subjects cannot utilize self-pacing older subjects are placed at a distinct disadvantage. In an effort to keep up with a machine-determined pace older subjects have been known to spontaneously reduce the demands of the task (for example, by rounding off the corners of a zig-zag pattern). Unfortunately, this strategy is counterproductive because in rounding off the corners to speed up, they fail to meet the accuracy demands of the task (Welford, 1977). To avoid encouraging similar behavior it may be suggested that subject-paced instruments would be more appropriate in examining the performance of older subjects.

McPherson (1983) also pointed out other means by which the elderly may compensate for performance decrements. These include, "...using a different sense modality to a greater extent, (lip reading to compensate for a hearing impairment), intensifying (with a hearing aid) or correcting (with eye-glasses) the stimulus, and using experience to predict or identify the stimulus (knowing the shape of a stop sign)" (McPherson, 1983, p.179). This latter strategy of using their experience to anticipate outcome may help explain why elders "round off corners" when facing machine-paced tasks. In situations where the pace is too fast or the presentation of the stimulus too brief, the elderly may ask for the information to be repeated. Colavita (1978) suggested that as one ages there is an increase in the sensory threshold to excitation and so more sensory stimulation is necessary before detection will occur. Welford's (1977) argument - that with age there is a lowering of the signal to noise ratio in the brain - followed a different path but came to the same conclusion, that with age there is an increased need for more of the information before a response can be made with any certainty. In order to ensure that they have had time to process enough of the available information the elderly sometimes incorporate various strategies (Arenberg & Robertson-Tchabo, 1977; Canestrari,1963; McPherson, 1983; Welford, 1977; etc). Sometimes their choice of strategy is a poor one (Coyne et al., 1978; Kleinman & Brodzinsky, 1978). Sometimes the elderly are forced to rely on their past experience to offset the loss in present efficiency (McPherson, 1983).

Whatever the means, to the elderly "...these compensatory mechanisms are particularly important in problem solving or in decision-making tasks. Thus, with increasing age, adults become not only less accurate in problem solving but also slower" (McPherson, 1983, p.204), due to a growing dependency on compromises made between speed and accuracy as a function of their own abilities and the demands of the task. These compensatory mechanisms, although not used by all older people seem to be related to their perceived sense of competence, and as was pointed out before not all perceptions of older adults are favourable (McPherson,1983).

Stage Three, the Effector Mechanism

Having perceived and identified the stimulus, then having decided what the course of action should be, the individual is now left with the task of carrying out the selected response. The effector mechanism is responsible for organizing the specified motor commands in order that the right muscles are brought into play in the correct sequential order, that is, it initiates the motor program. Efficiency is the hallmark of a proficient effector mechanism. The Motor Programming Model is a means of describing movement prouction. A motor program is characterized by specifying the values of one or more movement parameters or features. The motor program is similar to an array whose basic features are invariant but whose flexibility allows for an assortment of related movement patterns (Schmidt, 1982). Several parameters have been shown to affect reaction time and therefore are believed to contribute to the composition of motor programs. These parameters may include: (1) the overall speed of a response (Glencross, 1973); (2) the "gain" of the force magnitude of the musculature involved; and (3) a variable scaling that allows for the generation of similar movements but of differing size (Merton 1972).

While these programs may constitute the means by which a movement is processed, are all of these muscle commands processed in the same fashion when the original movement has to be modified or corrected? If this modification requires a brand new goal, with intervention of new muscle groups, then a new motor program has to be formulated. A case in point is when the subject inaccurately anticipates both the direction and the location of the next target on a pursuit tracking task, starting towards a target position and then realizing the mistake, by appropriately adjusting the movement, correct alignment may be achieved. However, if the modification of the movement requires only a change in parameters, such as velocity, an alteration in the value of the parameter, and not in the program has to be made. As in the previous example, if only the distance of the target is misjudged the correction of an under- or an over-shoot requires, respectively, a continuation of or a reversal of the movement. In turn, as a result of these modifications to the movement, reaction times may also be affected (Quinn & Sherwood, 1983; Vince & Welford, 1967).

Most germane to the present study are the effects of these modifications on certain dependent measures in a pursuit-tracking task. Latency in pursuit tracking studies is "...measured as the period of time between the stimulus onset and the point at which the control and modified movement differ on some aspect of the movement (e.g., movement displacement, velocity, or acceleration)" (Quinn & Sherwood, 1983, p.165).

The latency of reversal modifications tend to be of longer duration than those of continuing modifications. One would then expect to see corrections of initial misdirection on a tracking task, where a reversal modification is required, demand more time to process than when the subject has established the appropriate direction but misjudged the distance to the target. It is possible that these reversal modifications are attended to at a higher level of a hierarchically structured programming process than are the continuing modifications, and therefore, require more time to be processed (Megaw, 1972b).

Henry and Harrison (1961) examined the effects on movements by presenting the cue to modify after the control movement had already been initiated. Subjects were unable to reverse a forward arm-swing movement in less than 190 msec. Henry & Harrison argued that this 190 msec delay was necessary for reprogramming of the movement to facilitate the reversal in direction.

Quinn and Sherwood (1983) examined changes in program and parameter variables in a rapid ongoing arm movement. The task required the subject to move a lever while both bicep and tricep muscle groups were monitored for electromyographic (EMG) activity. In the first condition the movement of the lever forward was accelerated. In the second condition the forward movement of the lever was reversed entirely. Regardless of which muscle groups initiated the "forward" movement, the results were the same. The response latencies for increasing the speed were approximately 50 msec faster than for the direction reversal condition. When the signal to modify the movement was illuminated either immediately, or 100 msec after the initial forward response had begun, there was a high probability of reversing the direction before the 400 msec movement time limit had expired. However, when the signal was presented 200 msec after response initiation there was only a 10 percent chance of reversing the movement in the 400 msec limit. This 200 msec period of reprogramming replicates the 190 msec required in the Henry and Harrison study (1961).

To briefly summarize, compensatory strategies are employed by the elderly to accentuate their strengths and/or to counteract their limitations. Their meticulous care in executing tasks is no longer thought of as being due to mere rigidity. Rather, this cautiousness is thought to be a learned response to neurobiological deficits (McPherson, 1983). In an effort to ensure accuracy older subjects often modify their pace or movement speed, in what is commonly referred to as a speed-accuracy trade-off (Birren, Woods & Williams, 1980; Botwinick, 1978). This trade-off illustrates not only the elderly's preference for accuracy, but also their dread of committing mistakes. It is almost as if to commit an error is to be totally incompetent, a label which understandably the elderly seek to avoid. It has been suggested that some forms of experimentation may actually create anxious situations in which the elderly do not feel comfortable, and as a result of their induced over-arousal, perform poorly (Arenberg & Robertson-Tchabo, 1977). Anticipation is another strategy often used. While using past experience frequently benefits performance, it may also limit one's ability to respond spontaneously (McPherson, 1983). The movement executed is not in response to the demands of the task and to stimulus presentation, but rather to the subject's expectations. As a result, the movement may have to be modified to become appropriate, and true to form, the more complex this alteration is, the longer it will take to process (Stelmach, 1982a), especially for the elderly (Megaw,1972b).

The two experimental tasks, those of Henry and Harrison (1961) and of Quinn and Sherwood (1983) resemble the correction of a response error. It is then appropriate to briefly discuss the causes and the means by which one corrects movement and action errors.

<u>The Causes and Rapid Corrections of Errors.</u>

According to Norman (1980a, 1980b, 1981) errors or slips fall into patterns which can be categorized. In conjunction with the three major mechanisms of the information processing model (perceptual, central, and effector; Welford, 1958), the formation of an intention to execute a movement is the result of many considerations. For example, relative to the perceptual mechanism, was the stimulus accurately perceived or was it distorted? Once perceived could it be identified with experiences from the past? Relative to the central mechanism, in selecting the response had enough information been considered to accurately assess the situation. In terms of the effector mechanism, have the response specifications been clearly defined or are they somewhat ambiguous? Has the entire process been accomplished quickly enough to meet the demands of the task?

Generally, in executing responses the selection of the actions to be performed is prepared at the conscious level, while the lower-level components of that action follow through with little need for further conscious effort, except at critical points. In short, the intention releases the control processes or "schemas" (Schmidt, 1975) and as a result the movement ensues.

In a theoretical sense short term memory (STM) describes the system that is used to register, encode, store, and retrieve information over brief periods of time. Hence, Welford (1958) hypothesized that decrements in short term memory due to aging could possibly account for the observed decline in learning ability and problem solving, and as a result, skilled performance (Arenberg & Robertson-Tchabo, 1977). The "...more complex tasks involving immediate memory produce more evidence of age-related decrements" (Kalish, 1975, p.36). Similarly, Craik (1977) found no reduction with age in the storage capacity of short term memory, but slowing in scanning of this information was observed, thereby increasing processing time which on tasks requiring rapid responses put the elderly at a distinct disadvantage.

To facilitate the understanding of novel situations new information may be processed just long enough for it to be associated with similar past experiences. This may be accomplished, in part, by " particularizing" the information,

"...a description that characterizes things at as high a level of abstraction as possible, because that form of abstraction takes less mental effort" (Norman, 1980b, p.46).

While these shortcuts save the expenditure of one's mental efforts and/or resources, they often lead to the tendency to see what is expected, rather than what actually is. In anticipation of a given set of stimuli, the performer waits for the onset of the stimulus and executes what is anticipated as the appropriate response. In doing so, the stimulus encoding and the response selection stages of the information processing model (Welford, 1958) are usurped entirely. Sometimes what has been expected does occur and the response is appropriate, but often the opposite is true. Anticipation is a strategy employed to enhance performance, but often errors occur as a result of misperceived situations.

Many slips are caught at the time they occur, while others are caught just prior to their occurrence, but with insufficient time to prevent them either partially or completely from taking place. "For a slip to be started, yet caught, means that there must exist some monitoring mechanism of behavior - a mechansim that is separate from that responsible for the execution of the act" (Norman, 1981, p.2). This mechanism could deal with feedback from the environment and/or from the movement itself. Was the actual movement performed that which was intended? Perhaps a selection error was committed whereby an alternative movement to that intended was carried out. Or after reviewing the situation was the intended movement really appropriate? In the case of tracking tasks these assessments of response suitability have to be made quickly in order for the subject to keep up with the task.

When the pace of the learning situation is not under the control of the older learner there is a concern that he or she might not be able to keep up with the ongoing visual or verbal explanation. The time to register material in long term memory increases with age, so that it is not only important to explain instructions at a suitable rate to older subjects, but it is also important not to distract them while they are committing this information to memory. Or better yet, let them discover on their own how to perform the task. Craik & Simon (1980) found that older people do not encode information in the same manner as do younger people. Hence, there arises the difficulty in examining the retrieval from memory, independently of the acquisition of information to memory. While semantic encoding leads to a more effective acquisition of information, it does not guarantee similarly effective retrieval. To offset this awkwardness Michenbaum (1972) advocated the use of self-instructional training programs which would provide the elderly with covert self-statements that may improve task comprehension and ultimately task performance. Even if not always practical, the validity of self-instructional training emphasizes the need for presenting older subjects with thorough instructions at their pace.

Although there has been no consistent demonstration of a reduction in the capacity of short term memory to attend to specific items (Craik, 1977), the ability to scan for these icons or items does seem to slow with age, as does the ability to store the image in long term memory (Birren, Woods & Williams, 1980; Botwinck & Storandt, 1974). Concerning the issue of scanning memory icons to categorize the recently received information, perhaps the reported inabilty of the elderly to ignore irrelevant items (Rabbitt, 1977) exacerbates this search. If in sifting through the schematic information stored in long term memory the older adult has disproportionately greater difficulty in locating the right item(s) to be used as reference material, confusion over what to use may result, and the observed slowing in processing ensue. This slowing of item categorization would be more detrimental to performance in situations where the pace of performance is not subject controlled, and most notable in tasks requiring quick decision-making.

When Gaylord and Marsh (1975) studied age-related difficulties in the speed of spatial cognitive processing they found that the older subjects generally have a higher (11 percent) error rate than their younger counterparts (5.4 percent). The task involved identifying whether pairs of perspectively drawn figures were the same or mirror images of one another. "For both groups, the greater the degree of angular orientational difference the longer was the response time" (Gaylord & Marsh, 1975, p.678). However, the older subjects took considerably longer to mentally rotate the two figures to test for congruence. So it would seem that although speed was sacrificed, the trade-off did not lead to increased accuracy.

In their study with young and old adult veterans (Milligan et al., 1981) found that the older subjects (55-70 years) made more errors on the task than did the younger subjects (20-35 years) especially errors of omission on the more complex serial learning task. The older subjects also took significantly longer to perform this task. At this point the reader is left with the question of whether speed was actually traded for accuracy. Had older subjects performed the task more quickly would they have made more errors? Since the opportunity to correct errors was not provided for in the design of this study, the question remains unanswered. To examine the extent to which individuals profit and learn from their mistakes, subsequent trials are necessary. Lehman and Kral (1968) and Murrell (1970) maintain that the elderly may gain more from practice than do the young, so that tests involving low numbers of trials may be assessing the relative adaptability of different subject populations to a new or novel situation, and not performance ability per se. With practice these noted age-related disparities may be reduced to capture the true essence of the effect of aging upon performance and learning. Hence, it is important to use repeated measures designs when assessing the potential of the elderly.

Laming (1979) and Rabbitt (1966) suggested that subjects seemed to be well aware of the fact that they have made an error even when no explicit knowledge of results (KR) was provided. Laming (1979) went on to add that after making an error, subjects make some adjustment to their decision process resulting in a decreased probability of error and an increase in response time on the following trial. Presumably, some small contrary adjustment to the decision process is also made following a correct response. This succession of adjustments maintains the decision process in dynamic equilibrium (Welford, 1980). "It has been well established that proprioceptive feedback serves as a regulatory mechanism that helps [the subject] S discriminate correct movements from incorrect ones and that [it] works in addition to other senses (eg. vision, touch) to make responses more proficient" (Schmidt & Christina, 1969, p.303).

Schmidt and Christina (1969) suggested that for subjects to use the proprioceptive feedback as a time standard, the pattern of feedback must be consistent. Then, if all factors are held constant one should expect to see more frequent and more accurate anticipation if proprioceptive feedback is increased through more frequent or longer movements, or by increasing the load carried.

Adams and Creamer (1962) and Schmidt (1968) hypothesized that proprioception may act as a mediator for anticipatory timing responses. Adams and Creamer (1962) theorized that if a subject makes a response at time t, the proprioceptive feedback from this response enters short term memory and then decays predictably with time. If an additional response is to be made at time $t + \Delta t$, where Δt is constant, the subject can learn to use the predictable properties of the decaying trace as a time standard. This results in a more accurate estimation of when time $t + \Delta t$ will occur. Schmidt and Christina (1969) found that absolute timing error tends to decrease with practice. In addition, the group receiving more and/or intense feedback produced fewer errors than the less intense feedback group. Similar results were found in Christina's (1971) temporal anticipation study where 32 male college students learned to temporally anticipate, with no preview, the coincidence of a moving pointer with a stationary one. Subjects in the high feedback group had to rotate a crank, hidden from view, 90 degrees with their left hand during the interval to be timed. Subjects in the low feedback group just positioned their left hand on the crank. Both groups had to lift their right middle and index fingers off a reaction key to mark the anticipated coincidence of the pointers. The high feedback group temporally anticipated with significantly greater accuracy than the low feedback group.

Of special interest here is the role of internal feedback in the phenomenon of rapid error correction. This phenomenon has been observed frequently in pursuit tracking tasks and in choice reaction time tasks where errors in direction are observed to be corrected in less time than is required in spontaneous responses to external stimuli. The explanation offered most often is that errors are detected centrally via the efference copy or anticpated motor schema, even before the movement begins. The higher centres of the central nervous system specify the exact musculature to be utilized, as well as the temporal sequence in which the muscles are to be activated in the desired movement. At the same time representations of the movement parameters are fed-forward to the musculature involved. In the event that feedback from the execution of the response does not match either these individual representations, or the overall model of that movement stored in memory, the discrepancy denotes an error. Correction of the movement ensues accordingly. "Therefore, the corrections were not in response to the external consequences of the original efferent command" (Diggles, 1981, p.2). Evidence for this lies in the assumption that long before input is ready the cerebellar nuclei can compute the correctness of the pyrimidial tract discharge (motor command) and return a modified version to the cerebellum facilitating corrections in approximately 20 msec (Eccles et al., 1967).

In her study of the rapid error correction of arm movements Diggles (1981) found 54 percent of the errors generated exhibited electromyographic (EMG) patterns of antagonist inhibition preceeding the actual error response by as much as 60 msec. This finding supports the notion that rapid error corrections are a central phenomenon, since the correction is evident even before the error has been made (Diggles, 1981). These results are in direct contrast to those of Schmidt & Christina (1969), Adams & Creamer (1962) and Schmidt (1969) who believed proprioceptive feedback was important in error detection. Perhaps these two opposing views are not mutually exclusive, but rather because they can occur simultaneously, play complementary roles in the correction of movement errors.

In a situation involving striking a rapidly moving target Schmidt (1968) found between reaction time and error a Pierson product-moment correlation of 0.73. A correlation of 0.04 was found between movement time and error. Schmidt interpreted these findings to mean that the subject's error was, in all probability anticipatory, and largely determined before the initiation of the movement. Further, after initiation of the response the subject was unable to alter his or her movement in response to the concurrent feedback of the response.

Movement times and reaction times showed a high degree of correlation of 0.63, "...indicating that the movement time and the starting time...[are]...preprogrammed" (Schmidt, 1968, p.641). Combined with the finding that the standard deviation of the subjects' reaction times were nearly twice those of their movement times, these findings support the view that subjects attempt to keep their movement times constant and vary their reaction times in response to the error on the previous trial (Schmidt, 1968). This then is in accordance with the aforementioned work by Laming (1979) regarding deliberate modifications to the response latency after an error has been committed in an effort to improve subsequent response accuracy.

Similarly, Rabbitt (1979), Rabbitt & Rogers (1977), and Rabbitt & Vyas (1970) found that subjects quite systematically make runs of increasingly fast responses, terminating in an even faster error. Having detected the mistake, the subjects then slow down their subsequent reaction times to "track" at a slower pace for which accuracy is more probable. The cycle then repeats itself. Welford (1980) also predicted this cyclic error-response pattern. While all subjects slow their subsequent responses in the wake of an error the older subjects reduce their speed much more drastically, and for a longer period of time than do the younger subjects. It is of importance at this time to note that the elderly, although slower than the younger subjects, were still concerned with, and capable of, detecting and subsequently correcting their response errors. "It seems that people need to detect errors in order to control their performance in continuous tasks" (Rabbitt & Rodgers, 1977, p.727). "Errors are rarely random or unsystematic occurrences but can be traced to causal factors and when discovered perhaps avoided" (Turpin & Buck, 1984, p.1). A low error rate is generally indicative of the subject's comprehension of the task and the instructions, as well as a concerted effort to comply with those instructions. As Pachella (1974) pointed out, the speed-accuracy relationship is such that when speed is at a minimum, small differences in accuracy could reflect large differences in the subject's intentions. Hence, there is a need to study errors whenever examining reaction times. The information that error analysis yields helps the researcher to better assess the nature of the response and the motivation of, and the competency of the respondent to monitor his or her peformance.

Through data derived from pursuit-tracking Buck (1982) has illustrated that movement time is related to two independent factors, movement amplitude and boundary distance, and further, that terminal accuracy (the w of Fitt's Law) is determined by boundary distance alone. Boundary distance is defined "...as the distance between the target and the boundary [or outer limit] of the display in the direction of movement" (Buck, 1976,p.1). In an earlier series of experiments altering movement amplitude and direction in varying conditions of knowledge of results and sleep deprivation, Buck (1976) found that as the distance between the target and the outer limit of the display the subject was moving towards in his or her alignment increased, overshoot rate increased. Subjects appeared to track as if faced with some insuperable barrier, and moderated their primary, ballistic movement in order to avoid coming into contact with it. The standard deviation of these attempts at alignment comprised the upper tail of their end point dispersion, as represented by the overshoot rate. It would seem that while movement speed varies directly with movement amplitude, movement accuracy, as determined by the overshoot rate, depends upon boundary distance. If movement amplitude is held constant, boundary distance holds an inverse relationship to movement time. These two relationships hold true for both the direct and the indirect versions of the tracometer. To briefly condense this discussion on error causation and correction, let it be understood that error reduction is integral to the learning process. Errors frequently result from misperceived situations, which in the case of the adult, may arise from age-related declines in visual acuity (Brebner & Welford, 1980; Hoyer & Plude, 1980). The observed slowing in the rate of information processing with age (Hartley, Harker & Walsh, 1980; Simon & Pourabagher, 1978) may incite subjects to rely on compensatory strategies, such as anticipation (McPherson, 1983). But as was discussed earlier, anticipation often leads to misperceptions, which in turn, result in errors. To offset the perceived need to employ these strategies it has been suggested that the instructions given to, the stimulus presentation, and the response elicited from the older subject all be at a pace directed by the subject. When response errors are committed older subjects allegedly slow their subsequent responses significantly more than do younger subjects. To ensure accuracy on following responses, and perhaps bolster their confidence the older subjects have been observed to continue to respond slowly for a longer period of time after an error than do their younger counterparts (Rabbitt & Vyas, 1970; Welford, 1980). This slowing illustrates two important points, first, that the elderly are able to monitor their performance accuracy, and second, that their penchant for accuracy above speed is a powerful influence on their performance.

To this point this review has concentrated on age-related changes affecting information processing. There are several physiological changes that relate to the area of motor skill processing that should also be mentioned. Certainly, there are other changes taking place in the aging process such as biochemical or biomechanical variations that limit response production. While these components are important, they are not within the scope of this study.

Physiological Changes Associated with Aging

In discussing the relative contribution of strategic factors and neurophysiological restraints in the observed slowing in the elderly, Welford (1977, p.470) stated, "...the question is important, not only from a theoretical point of view, but because fundamental changes are essentially a physical problem whereas changes of strategy may be amenable to training", and therefore, accomodated.

While this cognitive compensation may be important, there are those who believe that improved physical fitness may also benefit aging psychomotor performance. A major proponent for the use of physical fitness to retard the ontogenetic slowing has been Spirduso (Spirduso, 1975,1985; Spirduso & Clifford, 1978).

In 1975, Spirduso sought to ascertain the benefit, if any, of habitually active lifestyles upon psychomotor task performance. Four groups each containing 15 males were formed. The two younger groups, active and non-active (mean age = 24.5 years) were contrasted against the two older groups, active and non-active (mean age = 56.8 years). Simple reaction time, discrimination reaction times, and movement times were measured. Both main effects of age and activity level were significant. In terms of simple reaction time and movement time the order of performance, from fastest to slowest was as follows: younger active, older active, younger non-active, and older non-active groups. In the discrimination reaction time task both younger groups scored faster responses than both of the older groups, although in each age group the active were faster than the non-active subjects. Spirduso maintained that a healthy cardiovascular system resulting from lifelong physical activity enhances cerebral circulation and, "...maintains an optimum neuronal longevity as well as processing efficiency" (Spirduso, 1975, p.439). She then concluded that, "...the best protection against senile involution of brain cells in cerebral activity is exercise, which unlike mental activity, stimulates metabolism, blood circulation, digestion and glands of external secretion" (Spirduso, 1975, p.439).

In a replication of her earlier research, Spirduso & Clifford (1978) discovered that older active men, whether in competitive (racquet sports) or in non-competitive (running) activities, have significantly faster simple reaction, choice reaction, and movement times than do their sedentary counterparts. In addition, these older active groups are also significantly faster than the younger non-active group on these measures. The older racquet sports group, involved in a sport which demands quick decision-making to an ever changing environment and continuous stimulation of the central nervous system were significantly faster than the older running group. But this sport-related difference was not apparent between the two younger active groups. In fact younger runners proved to be faster on movement times associated with both the simple and choice reaction time tasks. The older runners were faster than the older racquet sports group only in terms of movement times associated with the choice reaction time task. All in all the increased demand on the participants of the fitness program over their sedentary counterparts may have retarded the decline in both physical health, and of consequence to the present study, decision-making abilities associated with aging.

In contrast to the findings of Spirduso (1975) and Spirduso and Clifford (1978), Botwinick and Storandt (1974) failed to find a significant relationship between the levels of activity and reaction time in older subjects. Instead it appeared that the (undefined) benefits derived from activity were limited to the young. Perhaps increased activity levels do offset age-related changes in reaction time (Spirduso, 1975;1985), but are just not powerful enough to overcome the tremendous deficits in performance accompanying cardiovascular disease. Since Botwinick & Storandt (1974) utilized subjects with increasing levels of cardiovascular disease the suggestion that exercise may alter the age-reaction time relationship in their study could not be substantiated. It seems that cardiovascular status had a more powerful influence on reaction times than did activity level. In order to control for this potent variable subjects in psychomotor ability assessments should be screened for cardiovascular status, lest they bias group performance scores.

Earlier, DeVries (1970) had observed improvement in physiological function of older subjects as a result of participation in a training regime. DeVries concluded that "...the trainability of older men with respect to physical work capacity is probably considerably greater than has been suspected and does not depend upon having trained vigorously in youth"

(DeVries, 1970, p.335). Unlike Spirduso (1975) or Spirduso and Clifford (1978), Devries (1970) suggested that improved cognitive functions resulted less from physical conditioning than from arousal of the central nervous system. These studies on physical fitness and aging are good examples of the age old adage, "use it or lose it". It would seem that the maintenance of one's physical and cognitive capabilities enhances the preservation of one's sense of personal integrity. Hence, there is a need to screen subjects for cardiovascular fitness if one wishes to examine the true potential of normal healthy adults. It has been suggested that those who have maintained their cardiovascular integrity, evidenced by the absense of cardiovascular and cerebrovascular diseases, have also sustained their intellectual capacities, and in particular their decision-making ability which directly influences psychomotor skill execution (Spiduso, 1985). The more obvious external physical changes such as the reduction in subcutaneous fat and muscle mass (perhaps even height) markedly alters physique. For those whose sense of identity is closely linked to their body image and possible former performance prowess, such changes may greatly reduce self-esteem (McPherson, 1983) and perhaps even change behavior (Milligan et al., 1981). Expectations regarding what is socially acceptable for their age may serve as cogent constraints to participation in physical activity by the elderly. Yet, "...the evidence suggests that the benefits of physical activity may be even more important as age increases. In fact, it is hard to imagine a group for which chronic exercise is more important in terms of enhancing the quality of life" (Spirduso, 1985, p.7).

Internal changes such as decreased muscle mass and elasticity, reduced water content and increased fat to muscle cell ratio, increased osteoporosis due to a loss in minerals and decreased bone size, as well as limited range of flexibility all serve to reduce ability to perform even simple tasks (McPherson, 1983). Reports indicate that the relative number of fast contracting glycolytic fibers (Type II), essential for power or strength performances, declines linearly with age from the 30's to the 70's. Consequently, the percentage of slow oxidative fibers (Type I), integral to endurance performances, is proportionately greater than the Type II fibers in older individuals. This may help explain why older individuals tend to gravitate towards endurance activities, such as marathon running (Spirduso, 1985). Associated with these internal decrements is a loss of mobility which in turn could affect one's sense of competence and very probably one's adroitness when performing motor skills (Milligan et al., 1981).

To summarize briefly the discussion on the effects of ontogenetic change on information processing, for a movement or a skill to be performed confidently and accurately its initiation, execution, and termination characteristics must have been identified in the motor commands issued by the brain. It has been proposed that through learning an individual retains in memory a fixed plan of action that specifies the temporal and sequential properties of a total skill. Once initiated, this plan of action regulates a myriad of motor commands that can control the entire movement in the absence of feedback.

Essential to this plan are the organizational principles of hierarchy and sequence. In addition, movements within a plan of action must be executed as they have been specified or the plan will break down and most likely result in an error. For the plan to be considered viable for executon it must first be hierarchically organized, implying that the various operations be categorized and then ordered relative to the sequence in which they are to be carried out (Marteniuk, 1976). As is evidenced by the literature reviewed so far the aging adult is subject to deterioration in not only the perceptual mechanism function (Hoyer & Plude, 1980; Kline & Szafran, 1975; Lee & Pollack, 1978; Panek et al., 1977), but also in the central (Hartley, Harker & Walsh, 1980; Rabbitt, 1977; Simon & Pourabagher, 1978; Welford, 1980) and the effector mechanism capacities as well (McPherson, 1983; Milligan et al., 1981; Welford, 1977).

Motor Performance and Cardiovascular Health

For the most part, this review has centered on research concerning the effects of ontogenetic change on motor performance utilizing "healthy" subjects. But not all adults escape illness. It is not the function of this paper to review all of the literature on diseases incurred by the aging adult; however, in studying aging, it is important to distinguish between the effects of aging per se, and the effects of pathological conditions which sometimes, although not necessarily accompany chronological age (Speith, 1965). The behavioral profile of individuals predisposed to coronary heart disease (CHD) suggests an influence on their motor skills and the problem-solving strategies they use, and so is of interest to motor behaviourists (Krantz & Manuck,1984).

The Western Collaborative Group Study conducted by Freidman et al. (1968) attempted to link behavioral variables, and motor performance abilities to the etiology of coronary heart disease. These investigators have defined a coronary-disease-prone (Type A) behavior pattern as,

> "...a characteristic action-emotion complex which is exhibited by those individuals who are engaged in a relatively chronic struggle to obtain an unlimited number of poorly defined things from their environment in the shortest period of time, and if necessary, against the opposing efforts of other things or persons in this same environment" (Abrahams & Birren, 1973, p.471).

Individuals exhibiting a Type A behavior profile are generally highly competitive. They like to establish their own work pace but are often involved in multiple activities having time restrictions. Type A individuals seem to be extraordinarily alert, and they "...tend to be impatient with slowness, even to the point of hurrying conversations or supplying words for persons with whom they are speaking" (Abrahams & Birren, 1973, p.471). On the other hand, Type B behavior has merely been described as the, "...absence of the overt manifestation of Type A characteristics" (Abrahams & Birren, 1973, p.471). Relative to the earlier cited findings regarding limited attention allocation, and a slowing in the processing rate with age, if Type A individuals insist on being involved in multiple activities having time restrictions they may be defeating their own efforts. On the other hand, if they have always approached situations in this way perhaps their decision-making is maintained with the life-long pattern or practice.

There have been several studies dedicated to elucidating the differences between the Type A and Type B behavior personalities. A brief survey of only those studies concerned with psychomotor abilities as a function of the Type A versus Type B behavior profile follows.

Using a modified version of the Birren, Riegel and Morrison (1962) ten-choice serial reaction time task, mentioned earlier, Speith (1965) tested 338 men aged 35 to 55 years. There were nine groups in all, including false-positive subjects, those with mild or moderate congenital or rheumatic heart defects, and those with arteriosclerotic or coronary disease without hypertension some of which had old myocardial infarcts, and some hypertension. Still other groups had hypertensive diseases but with blood pressure maintained at normotensive levels by medication. The last pathological group had histories of cerebrovascular accidents or evidence of cerebrovascular diseases. All of these subjects were then matched with healthy same-aged volunteers. The groups also performed two other tests, the Wechsler Adult Intelligence Scale (WAIS) Block Design and the Halstead Tactual Performance Test, as outlined by Speith (1965).

The study demonstrated quite conclusively that subjects suffering from arteriosclerotic coronary heart disease, or those who showed evidence of old myocardial infarctions, and especially those with hypertension performed less ably than did their healthy contemporaries on a wide variety of self-paced tasks in which physical effort involvement was minimized. This poorer performance (slower reaction time) was also manifested by those who had recovered from the acute symptoms, and also by those who exhibited only a moderate degree of these coronary - heart diseases.

Of relevance to the present study, the coronary heart disease subjects made more errors even though working more slowly than the healthy subjects, suggesting that the coronary heart disease subjects did not achieve accuracy at the expense of speed, "...their slowness was not in the 'doing' but in the 'deciding what to do'" (Speith, 1965, p.374) and therefore reflected central processing adaptation beyond that normally encountered with aging.

To test the hypothesis that this adaptation to the central processing mechanism may occur even prior to the overt physical manifestation of coronary heart disease rather than as a result or consequence of the event, Bortner and Rosenman (1967) compared the responses of Type A and Type B individuals. The hypothesis was confirmed, in that Type A subjects did have longer reaction times than did Type B subjects. In a replication of this study, Abrahams and Birren (1973) compared the reaction times of people with a predisposition to coronary heart disease (Type A) as assessed by the Standard Situation Interview developed by Friedman (1969), to those not prone to coronary heart disease (Type B). Their results showed that subjects manifesting a coronary-disease-prone behavior pattern had significantly longer response latencies for simple reaction time tasks. Type A subjects were disproportionately slower than Type B subjects in the choice reaction time tasks where target location certainty necessitated a greater dependence on, or involvement of central mechanism decision-making. Abrahams and Birren (1973, p.478) suggested that, "...perhaps psychomotor slowing existed prior to the acute onset of CHD and may be the consequence of psychophysiological antecedents to the disease".

Similarly, Botwinick and Storandt (1974) found subjects with differing levels of cardiovascular problems have significantly longer reaction times than do healthy subjects. The suggestion that habits of exercise might alter the age-related reaction time slowing for older subjects was not substantiated. It was tentatively suggested that whatever "...influence exercise may exert on RT (or what common mechanism may underlie both level of exercise and RT - a mechanism such as a vigorous psychobiological constitution, for example) is limited to the young" (Botwinick & Storandt, 1974, p.548). These studies seem to support the earlier supposition that cardiovascular status may be a powerful predictor of psychomotor ability.

Three explanations have been offered for the observed cardiac-related motor performance results. The first explanation emphasizes subclinical cardiovascular or cerebrovascular oxygen insufficiency in Type A subjects which in turn, may slow processing efficiency (Abrahams & Birren, 1973; Kalish, 1975; Speith, 1965; Welford, 1978, 1980). The second suggests that at least some part of the central nervous system (CNS) of the coronary-disease-prone subjects mimics the functioning of the aging adult, perhaps due to deterioration of the CNS beyond that required for maintaining optimal proficiency (Abrahams & Birren, 1973; Kalish, 1975; Spirduso, 1975, 1985; Spiduso & Clifford, 1978). The third suggests that just as there may be a reduction of the signal to noise ratio with age there may also be a difference in Type A versus Type B responsivity. It has been proposed that higher initial background levels of activation in the Type A subjects effectively raises the threshold against which incoming signals have to be detected (Abrahams & Birren, 1973). A lowered signal to noise ratio could indirectly affect motor performance by impairing the ability to prepare responses, hold states of readiness or formulate expectations (Abrahams & Birren, 1973; Welford, 1980).

From these studies on the influence of cardiovascular status on motor performance it seems that people with symptoms of coronary heart disease, or even those with a similar behavioral profile, encounter slowed responses similar to those seen in the aging adult. It would appear that the effects of aging on motor performance are compounded by the additional variable of coronary dysfuncton.

The foregoing discussion on the effect of cardiac dysfunction on motor performance, including accuracy, underlines two important points. The first is the need to screen out those subjects who have actually suffered a major illness such as cardiovascular or cerebrovascular disease when assessing the effects of normal aging. The second illustrates why those with a pre-disposition to coronary heart disease according to the Type A versus Type B behavioral profiles should also be controlled, in subject populations using a motor performance task. Specifically, this is done in an effort to ensure a truer representation of normal motor performance in older people.

Gender Differences with Respect to Motor Performance

Because Type A and Type B traits are evident in both sexes females must also be represented in studies examining the effects of cardiovascular behavior on psychomotor performance with age. To date, there is evidence of lack of consistent age and gender matching when comparing the performances of men and women on various tasks (DeVries, 1970; Fogliani-Messina et al., 1983; Kirchner, 1958; Salthouse & Somberg, 1982). Since research in the past has demonstrated fairly consistent gender-related differences in motor performance it seems incongruous that more care has not been taken to ensure equal representation in subject samples. Not to belabour the gender issue but more to identify some of the observed gender-related differences in motor performance the following studies are cited.

Noble et al. (1964) measured response speed across most of the life span (from 8 to 87 years). The two sexes were found to have similar responses until their pre-teen years of 10 to 14, where the females are faster than the males, probably because of their relative maturity at this stage. Males then surpass females and remain faster until quite late in life (71 to 84 years), at which point they are generally no longer quicker and are even slower than females. These gender differences have been replicated in other studies such as those involving response to visual or auditory cues (Bellis, 1933) or in pressing and releasing a key to the onset of a stimulus (Engel et al., 1972).

Other researchers have found differences between genders on psychomotor variables to be only marginal (Botwinick & Storandt, 1967; Botwinick & Thompson, 1966; Gottsdanker, 1982). Botwinick and Thompson (1966) distinguished pre-motor time from motor time using EMG records, and concluded that the entire gender difference effect lay in the premotor time, "...implying that control rather than muscular factors were involved" (Welford, 1980, p.347).

It is important to note that these gender differences did not dissipate with practice (Botwinick & Thompson, 1966; Noble et al., 1964; Welford, 1980). To date, attempts to explain these differences have been vague. Often the ratio of males to females in performance studies has been disproportionate and so comparisons are restricted, and results uncertain.

Similarly, while some studies may begin with evenly matched healthy and pathological groups, because of severe attrition they may end with poor comparisons and overgeneralized results. Another frequently encountered control problem in motor performance research concerns the use of large age spans of 20 to 30 years to represent the elderly when using much smaller age spans of 4 to 10 years for younger groups (Fogliani-Messina et al., 1983; Kirchner, 1958; Salthouse & Somberg, 1982). Oversights such as these and those already mentioned, on the part of experimenters have led to the the detriment of gerontologic research and consequently, to the image of the elderly at large. Of importance to the present study is the notion of confidence. There is evidence to suggest that males have more confidence in performing novel tasks than do females. Females are also stereotyped as emotionally "over-reactive" to failure (Williams, 1977; 1979). Consequently, in the present task females may have slower reaction times than males, and they may also slow their reaction times following an error response moreso, and for a longer period of time than will males. Recall ~~that~~ this slowing in response time is thought to allow the subject time to re-establish his or her confidence in task exection (Rabbitt, 1979; Rabbit & Rogers, 1977; Rabbitt & Vyas, 1970; Welford, 1980).

Summary of the Review of Literature

To summarize this survey of related literature, let it be understood that age-related changes occur in all three of the major mechanisms of the information processing network. From the initial reception of the signal (Colavita, 1978; Hoyer & Plude, 1980; Lee & Pollack, 1978) to the eventual production of the response (McPherson, 1983; Milligan et al., 1981; Welford, 1977, 1980) adaptations are made to observed age-related physiological and biomechanical decline. While not discounting the importance of peripherally located limitations, there is a growing trend in the literature to emphasize the effects of aging on cognitive decision-making aspects of behavior governing movement response (Welford, 1977, 1980). Supporting this contention, research in the area of motor performance has consistently demonstrated reaction time changes with age disproportionately increase as a function of task uncertainty (Birren, Riegel & Morrison, 1962; Gottsdanker, 1982; Welford, 1977; 1978), or as in the case of the present study with directional probability. For example, simple reaction time is said to increase 26 percent between the ages of 20 to 60 years while choice reaction time changes for the same period may range from 27 to 51 percent depending on the difficulty involved in the execution of the task (Birren, Riegel & Morrison, 1962). Similarly, age-related changes in movement time also increase as a function of the number of muscle groups involved (Birren & Botwinick, 1951; Morikyo & Nishioka, 1966; Pierson & Montoye, 1958; Rose, 1982; Welford, Norris & Shock, 1969). For example, while repetitive tapping movements between two targets show little change with age (Morikyo & Nishioka, 1966; Welford, Norris & Shock, 1969) more elaborate movements requiring greater concentration such as writing digits or tracing complex patterns have shown very substantial (60-120 percent) changes with age (Birren & Botwinick, 1951).

In response to these performance decrements the elderly often employ compensatory strategies, such as caution and anticipation. Cautiousness is no longer interpreted as involuntary rigidity, but rather as a deliberate conscious adaptation to neurobiological changes (McPherson, 1983). The elderly seem very concerned about committing errors and prefer not to risk committing an error for the sake of speed (Calhoun & Hutchison, 1981; Herrick, 1983). It has also been suggested that there is a physiological need to access more of the available information before making a decision with any certainty, due to the increase in the sensory threshold to excitation (Colavita, 1978), and possibly, the lowering of signal to noise ratio in the brain (Welford, 1977). Anticipation of stimulus information may facilitate reaction time, but it does not guarantee that the response produced is appropriate. It might be suggested that if older subjects allocated more time to assessing the stimulus-response compatability, fewer response errors would result. Yet the validity of this latter approach may seem to be greatly outweighed by the necessity to do something, to respond. In situations where the presentation of the stimulus is brief, or the time to respond short, the elderly are at a distinct disadvantage. This is because the rate of processing visual stimuli is slower in the elderly, even though the processing stages are virtually the same (Hoyer & Plude, 1980; Lee & Pollack, 1978; McPherson, 1983). The encoding stage of the central mechanism in information processing seems to incur the greatest decrement with age (Craik & Simon, 1980; Simon & Pourabagher, 1978), perhaps as a result of, or in addition to, their trouble ignoring irrelevant stimuli or items (Farkas & Hoyer, 1980; Hartley, Harker & Walsh, 1980; Rabbitt, 1977).

Apparently the elderly rely more on expectations of stimulus information, and resultant response specification, than do younger adults (Welford, 1977). This, combined with the slower information processing noted in the elderly (McPherson, 1983; Rose, 1982) may have important implications in the observed higher error rate in older adults (Fowler et al., 1983; Gaylord & March, 1975; Milligan et al., 1981).

Subjects are well aware that they have made an error when it occurs (Laming, 1979; Rabbitt, 1966) and generally slow their subsequent responses in order that accuracy may be regained. Older subjects, perhaps because of their more intense fear of failure (Kalish, 1975), slow their subsequent reaction times much more, and for a longer period of time after the error has been committed than do younger subjects. If one considers the hypothesized role of internal feedback via efference copy in rapid error corrections, and the finding that changes in peripheral sensory mechanisms with age (Landahl & Birren, 1959; Szafran, 1951) may impair the processing of feedback, the slowing with age in responses following an error may be more readily understood.

Researchers investigating the subject of error responses have concluded that varying degrees of coronary heart disease involvement, even the predisposition to the disease, influences information processing efficiency, in particular, that of the central mechanism (Abrahams & Birren, 1973; Bortner & Rosenman, 1967; Botwinick & Storandt, 1974; Speith, 1965). Speith (1965) has concluded that coronary heart disease patients make more psychomotor errors than their healthy counterparts. It has been suggested that those predisposed to cardiac heart disease can be identified even in the absense of overt symptoms by their written responses to a questionnaire (Jenkins, Zyzanski & Rosenman, 1967; Prior, Goodyear & Holen, 1983). In addition to this, consistent gender-related differences in reaction times have been demonstrated (Botwinick & Thompson, 1966; Noble et al., 1964; Welford, 1980), although the differences in error rate with either gender or cardiovascular behavioral profile have not been sufficiently delineated.

Motor learning and the execution of a motor skill may be seen as a set of processes involved in practice with, or exposure to something leading to a relatively permanent change in skilled behavior. Overall, it involves a distinctive comprehension of how one learns to perceive and abstract relevant information from the environment, and from movement, and further, how this informaton is applied to organize and control subsequent movements including the correction of errors. Necessarily, those variables confounding comprehension and movement production must be identified and where possible controlled for, in order that a realistic appraisal of the aging motor processing system be achieved. To this end, the following study has been developed.

Hypotheses

Based upon the preceding review of literature and the pilot work already performed the following relationships regarding the relative contribution age, gender, and cardiovascular behavioral profile make to motor performance have been predicted:

Related to Performance Speed:

(1) Younger subjects are significantly faster in performance speed measures than are older subjects.

(2) Male subjects are significantly faster in performance speed measures than are female subjects.

(3) Type B subjects are significantly faster in performance speed measures than are Type A subjects.

Related to Performance Accuracy:

(4) Younger subjects are significantly more accurate than are older subjects.

(5) Male subjects are significantly more accurate than are females subjects.

(6) Type B subjects are significantly more accurate than are Type A subjects.

Related to Adaptation to Response Errors:

(7) Correct reaction times immediately following a response error are significantly faster for younger subjects than for older subjects.

(8) Correct reaction times immediately following a response error are significantly faster for male subjects than for female subjects.

(9) Correct reaction times immediately following a response error are significantly faster for Type B subjects than for Type A subjects.

CHAPTER THREE

RESEARCH METHODS

This chapter is concerned with the methodology employed in this study, including an Overview, an explanation of Subject Selection, Apparatus, Procedures and Statistical Analysis.

Overview

The investigation was confirmatory in nature. In an attempt to examine the effects of the normal aging process, gender, and cardiovascular behavioral profile on psychomotor abilities, those persons exhibiting symptoms of either cardiovascular or cerebrovascular dysfunction were restricted from participating in this study. A brief medical history of the subject's illnesses and present medication was noted in so far as it related to their psychomotor abilities. Subjects ranged in age from 55 to 84 years. Each subject was required to perform a series of eight trials on a step-input pursuit tracking task in order to assess his or her performance speed, accuracy, and reaction to the commission of an error. Inherent in the task, as fixed by the instrument, are both varying aspects of directional probability (0.25, 0.50, 0.75, and 1.00); and movement amplitude (41, 82, 123, 164 mm); and boundary distance (1, 2, 3, 4). Target location was randomized throughout the (100 light) trials so that each of the twenty between-target movements appeared five times.

In addition to the pursuit tracking task all of the subjects were asked to complete the Jenkins Activity Survey (Jenkins, Zyzanski & Rosenman, 1969). This written questionnaire characterizes the possible predisposition to coronary heart disease on a Type A versus Type B behavioral profile.

Subjects

One hundred and twenty adults between the ages of 55 and 84 years participated in this study. There were 10 men and 10 women in each of the six age groups: 55-59 years, 60-64 years, 65-69 years, 70-74 years, 75-79 years, and 80-84 years.

To be eligible to participate in the present study, subjects had to meet strict standards regarding their visual acuity and cardiovascular fitness status. They must have had normal, or corrected to normal vision. They must never have suffered from symptoms of coronary heart disease, such as a heart attack or hypertension. They must never have suffered a cerebrovascular accident (stroke). They must not have had a sensory or a biomechanical handicap which might impair their ability to perform the task. Finally, they must have been able to answer, coherently, questions regarding their medical history, age, and place of residence.

All of the subjects were recruited from the Ottawa area on a volunteer basis.

Apparatus

The apparatus used to measure psychomotor performance on a pursuit tracking task included the National Research Council tracometer and control units (Buck, Leonardo & Hyde, 1981). The tracometer is an instrument capable of measuring both performance speed and accuracy variables concurrently, yet independently. Through the randomization of target presentation the tracometer effectively safeguards against continued subject anticipation. While the subject may partially prepare for the direction of the next target (depending upon intrinsic directional probability) there is very little opportunity to prepare for the amplitude of the upcoming movement. Of utmost importance to the present study, the tracometer is subject-paced, and portable.

The tracking unit (see Figure 2) presents a 2.4 mm target at each of five positions set 41 mm apart along a 188 mm arc of 180 mm radius. The manually operated control wheel requires an applied torque of 14.2 g.m to initiate movement and has an inertia of 9.56 $g.m^2$. This steering wheel drives (a) a pursuit pointer set up in a 1:1 ratio, and (b) a potentiometer set up in a 1:4 ratio (Buck, Hyde, Isnor, Leonardo, and Trumbley, 1982). It should be noted that in this study the indirect steering model of the tracking unit was employed, such that as the subject steers to the left the pursuit pointer moves to the right (and vice versa). This particular version was chosen in order to increase the novelty of the task.

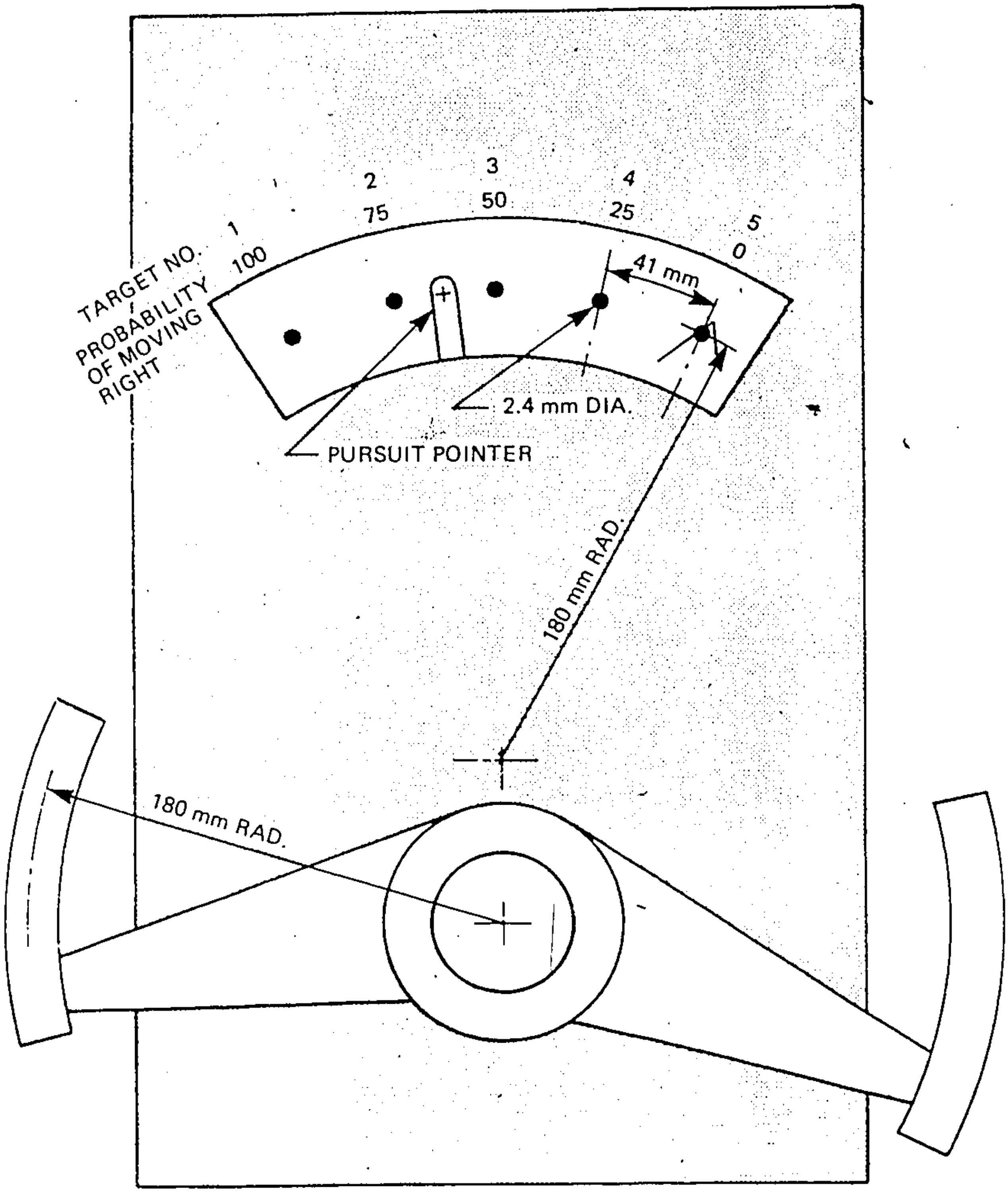

Figure 2 The National Research Council Tracometer Tracking Unit

When a target is presented, a series of events ensue. The subject must first detect the illumination of the target, including its position relative to the present location of the pursuit pointer. The subject must then initiate the movement of the pointer towards the target. If the subject inadvertently, or because of anticipation, steers in the wrong direction, or away from the target, this error must first be detected. Correcting the error involves the redirection of the pointer. With the pointer approaching the target, the subject attempts to align the pursuit pointer with the target area for an uninterrupted period of 200 msec. In the event that the subject allows the pointer to stray beyond the target area before the 200 msec criteria has been met, this overshoot must also be detected and the pointer redirected to accomplish alignment. The subject must then watch for the extinguishing of this target light which signifies satisfactory alignment. Should the target remain illuminated, the subject must recognize his or her misalignment, and then carefully renegotiate the pointer position until the light goes out. Then and only then should the subject look for the illumination of the subsequent target. When resting at position 1, the probability that the next target will appear to the right is 100%. When at position 2, there is a 25% probability that the next target will appear to the left, and a 75% probability that it will appear to the right. At position 3, there is an equal, 50% chance that the next target will appear to the left or to the right. The control unit monitors this movement generated output from the tracking unit potentiometer and then compares it with two reference voltages. The first of these represents the starting position and the second voltage the target position of each successive tracking movement. The monitored output is in the form of an amplified analogue measure of control wheel and pursuit pointer position and movement that is transcribed onto magnetic tape for future decoding. As the subjects track from one target to the next they follow a random sequence of targets established by the control unit. As alignment conditions are met, the reference voltage for the old target becomes the starting voltage reference for the next target. Figure 3 is a graphic example of some movement generated output. The original or starting position of the pursuit pointer in this figure is at target 4. The subject is attempting to align the pointer with target 2. Reaction time is calculated as the time interval between the illumination of the target (in this case, target 2), and the initiation of pointer movement beyond the 2.4 mm target area of target 4. In this illustration, the subject has initially steered the pointer in the wrong direction. This misdirection is labelled an error. The time the subject spends in correcting the error until redirecting the pointer represents the error time. This measure merely conveys how long the correction takes to execute, not when the decision to correct occurred. Movement time, or acquisition time is calculated as the interval from the instant the pointer exits the starting target area, until it reaches the presently sought after target, regardless of whether an error occurred. Should the subject pass over the far side of the target before the 200 msec criteria has been met, an overshoot is detected. The time it takes the subject to redirect the pointer to within the target area for the

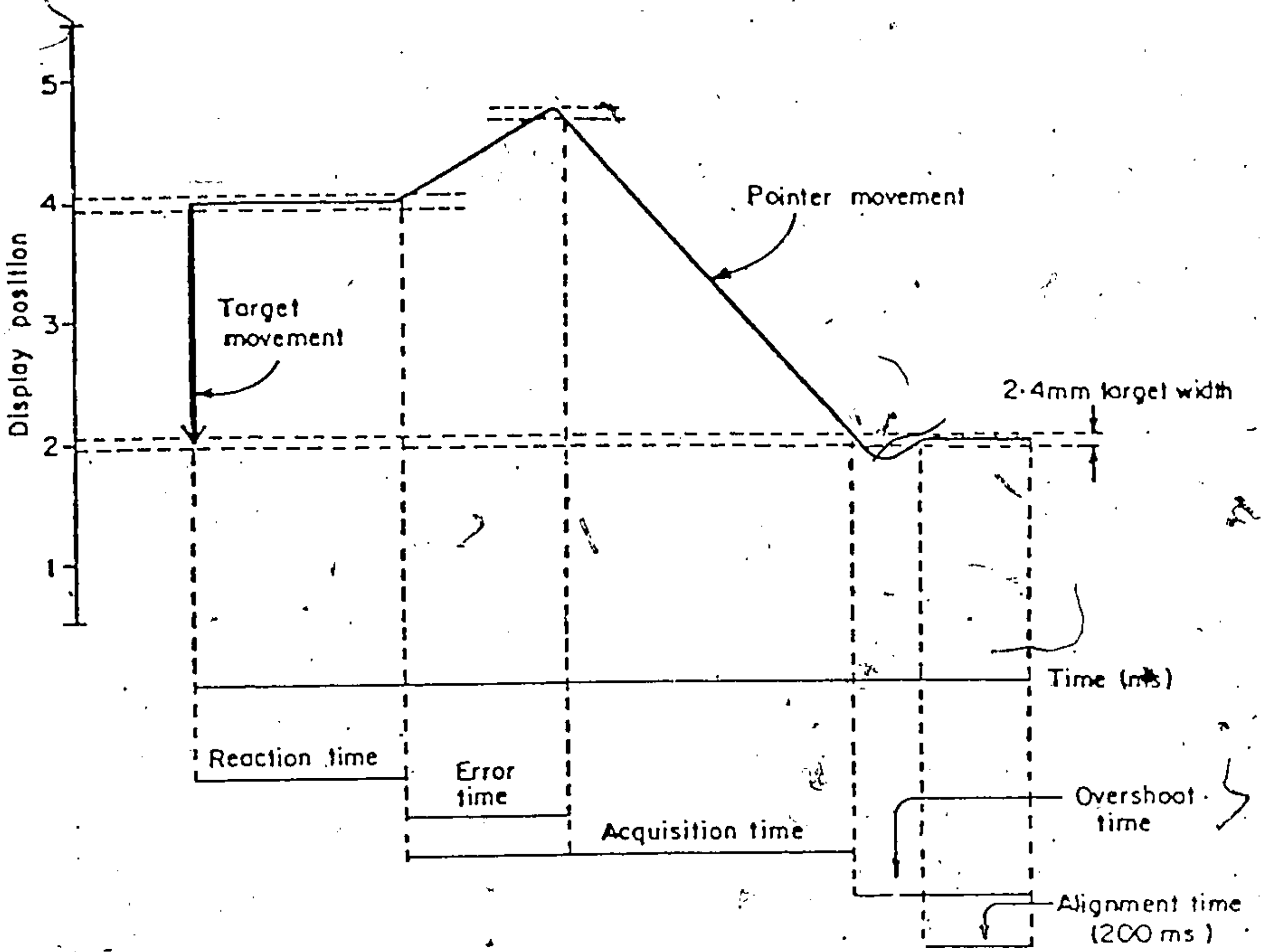

Figure 3 Events determining the beginning and ending of register counts

200 msec period constitutes an overshoot time. Total response time represents the interval between the illumination of the target and successful alignment of it.

Each of the correct reaction time and the non-overshoot movement time scores were categorized according to their respective levels of task difficulty, specifically directional probability for reaction time, and movement amplitude for movement time. Error rate and overshoot rate were averaged across levels of directional probability and boundary distance respectively, so there was only one score for each of these two measures per trial. Total response time is a global measure of performance and was also represented by one score per trial. The exception to this is the breakdown of the total response time into quintiles of scores monitoring the first to fifth exposure of the between-target movements within each trial. In summary, each trial is represented by four correct reaction time scores, four non-overshoot movement time scores, one error and one overshoot rate, five total response time X quintile scores, and one total response time score. To enhance the accuracy of these measurements the influence of atypical scores on group means was reduced. In conjunction with earlier tracometer use (Buck, et al., 1981), and inspection of the distributions for each of the present study's dependent measures, criterion magnitudes were established for each variable. For example, the time criterions for counting errors, and overshoots were 15 msec and 51 msec, respectively. Speed measures required both lower and upper magnitude criteria. Reaction times were restricted to those between 101 msec and 16,000 msec. Non-Overshoot movement times were restricted to those between 101 msec and 20,000 msec while overshoot movement times were limited to those between 1 msec and 40,000 msec. Depictions of the distributions for each of the dependent variables may be found in Appendix A.

The NRC tracometer, formerly called the stessalyser, is a step-input subject paced pursuit tracking task. It measures performance speed and accuracy variables concurrently. All of the performance variables are assessed at four levels of relevant within task difficulty such as directional probability, movement amplitude, and boundary distance. The instrument has been used successfully in the investigation of the influence of such factors as sleep deprivation and of drugs on motor performance (Buck, et al., 1981). The relationship between correct reaction time, error rate, and directional probability, and between movement time and movement amplitude, is congruous with Hick's Law and Fitt's Law, respectively, and illustrates the internal validity of the assessments. The product-moment correlation coefficient for 150 individual scores has been demonstrated at 0.78 on the first two trials, and 0.94 on trials 15 and 16 exemplifying the high degree of test-retest reliability.

In addition to their performance on the tracometer each subject was required to complete the Jenkins Activity Survey (Jenkins, Zyzanski and Rosenman, 1967). This survey is a pencil and paper questionnaire consisting of 52 multiple choice questions of which the subject selects the most appropriate response. The survey provides a profile of cardiovascular Type A versus Type B behavior. The survey provides four separate scores, each the result of a discriminant-function analysis. Each of the 52 questions or items is scored on one or more of the four scales. Each choice is weighted. The raw scale scores equal the sum of the weights for the respondent's choices on each of the items within that scale. For those not familiar with this survey a very laconic description of each of the four scales is included. The Type A scale examines the respondent's perception of, and style of approach to his or her environment. For example, is the environment challenging with time restrictions, or is it routine? Do subjects respond to situations immediately, or are they more conservative and methodical in their reactions? The Speed and Impatience scale surveys the rate at which respondents work. How many tasks are performed concurrently? Do repondents allow themselves sufficient time to recover from fatigue? The Hard Driving and Competitive scale investigates how respondents feel about competition. Is it enjoyable? Is it necessary to win regardless of the opponent? How do interruptions influence work productivity? The Job Involvement scale assesses the committment to one's job. Are respondents content with their present position? Do they make an extra effort to accomplish their tasks, such as taking their work home, or working at night or on weekends? Is the respondent considered dependable? Educational background is also classified. Three of the four scales were used to categorize the cardiovascular behavioral profile along the Type A--Type B continuum: (1) the Type A; (2) Speed and Impatience; and (3) the Hard Driving and Competitive Scales. A number of the subjects, especially those over 75 years of age were very reluctant to answer those questions relating to the fourth scale on Job Involvement. Some of these subjects were quite adamant that even as housewives raising many children during the depression, they had never held a "job". Similarly, other subjects who had worked on the family farm or followed in the family business, felt that their participation in their employment had not been a matter of choice, but rather of duty. Consequently, these subjects felt that the job involvement questions were not applicable to their situation. Because 35% of all of the subjects were reluctant to answer questions on this fourth scale, in conjunction with the questionable reliability of answers founded in retrospect, the job involvement scale was excluded from the Type A--Type B categorization. This profile has been demonstrated to be both a reliable and a valid predictor of coronary heart disease personality behavior patterns. According to Jenkins et al. (1967), the internal consistency reliability coefficients for the Type A scale derived by Kendall's tau b one-year test-retest and by the squared multiple correlation approaches were estimated at 0.83 and 0.85, respectively. A four-year test-retest coefficient of 0.82 compares favourably with reliabilities of other standardized psychological tests. The Type A scale was initially developed as part of the 1960 Western Collaborative Group Study into the predisposition and ultimate manifestation of cardiovascular disease. In an independent sample cross-validation, there was approximately 90% agreement for subjects scoring within one standard deviation of the mean on the Jenkins Activity Survey and the widely accepted Structured

Interview behavior pattern rating used by the Western Collaborative Group (Jenkins, et al., 1967). Admittedly, for those who are not familiar with heart disease literature, the labels Type A and the Type B convey little information. Still, they are the conventional means by which these personality behavior patterns are identified and so will be used in this study. Perhaps a cue might facilitate remembering what the labels represent. For example, Type A refers to those persons who approach life at an ACCELERATED pace, always impatient, and rushing about. Type B refers to those persons who have a more relaxed approach. Their BRAKES keep them from rushing into things.

Procedure

Each of the 120 subjects was tested individually. Subjects were asked to complete a single testing session consisting of eight trials. A brief (2 to 5 minute) rest period separated two blocks of four trials. Each session lasted between 40 and 60 minutes. Of the ten patterns of target movements available for use, only numbers one to eight were used, that is to say, the session began with pattern 1 and continued with a change of pattern with each successive trial for all eight trials. Subjects were seated directly in front of the tracking unit with the target display just below the line of sight. Indirect ambient room lighting was used whenever possible.

All of the details of the testing sessions for each subject were recorded on the Tracometer Test Record Sheets (see Appendix H). Subjects were instructed by the experimenter to align the cross on the pursuit pointer with whichever one of the five targets illuminated (see Figure 2).

It is important to note that when explaining the task to each subject, both alignment speed and accuracy were stressed. Subjects were warned against holding onto the control wheel handles too tightly, or with just one hand. Subjects were also reminded to remember to blink regularly. These latter precautions were taken in an effort to minimize possible physical and visual fatigue.

Subjects started each trial with the pointer resting in between Positions 4 and 5. Subjects were informed that the first light to appear in each of these 100 target trials would always be at Position 3 and that measurements would be made only after the precise alignment of this first target. So although 101 targets were presented on each trial, performance measures were only drawn on the last 100 targets. Knowledge of results was provided by the experimenter in the form of the total time taken, in seconds, to complete the entire trial.

Design and Analysis

In an effort to assess the effects of ontogenetic change on the ability to monitor and respond to errors the following indices were compared. It was hoped that through the collection of reaction time and movement time data, a better understanding of the location and the intensity of age-related changes may be achieved. Subjects were asked to perform eight trials. However, due to: (1) mechanical failure, which impeded the decoding of some of the trials for two of the subjects; and (2) experimenter error which led to the magnetic tape running out 10-15 targets before the completion of the run by two other subjects, not all of the 960 subject-trials were complete. Recognizing the immense difficulty in replacing four males over the age of 70 years, who still met the criteria for subject selection, a small compromise was made. After closely examining the group performances on each of the trials, it was decided that pairing the eight separate trials into four blocks of two trials would not distort or misrepresent the data. This concession would provide a means to save the balance of the data on not only these four subjects but of their respective groups as well. The scores of the first trial were averaged with those of the second trial to form the scores of the first block. The scores of the third and fourth trials were averaged to form the scores of the second block, and so on until the scores of the seventh and eighth trials became those of the fourth block. Only those blocks with complete data were used in the analyses.

Performance Speed Measures

To assess the global effects of aging, cardiovascular behavior profile, and gender upon the identification of, reaction to, and movement towards the target, response speed scores collapsed across levels of directional probability and of movement amplitude were subjected to a Gender X Age X Type X Block (of trials) multivariate analysis of variance with repeated measures on the last factor. These response speed scores include measures of total response time, correct reaction time, and non-overshoot movement time. Each of the 20 possible between-target movements appeared five times within each trial. The first time each of these 20 movements appeared constituted the first quintile. Additional appearances or repititions of these movements constituted the second, third, fourth and fifth quintiles of movements respectively. By comparing the responses of each subject to additional exposures of these movements it may be possible to tease out the effects of practise, fatigue, and/or boredom on a more discrete scale than is observed across trials. Because of the elaborate format in which the tracometer data is coded the quintile comparison of the total response time scores had to be analysed using a Gender X Age X Type X Quintile X Block (of trials) univariate analysis of variance with repeated measures on the last two factors.

Examination of the effects of aging, cardiovascular behavioral profile, and gender upon the use of advance information in preparing for upcoming target location, was mediated by the comparison of correct reaction times at the four different levels of directional probability. Only the reaction times for correct responses were subjected to a Gender X Age X Type X Directional Probability X Block (of trials) univariate analysis of variance with repeated measures on the last two factors.

The non-overshoot movement times were analysed using a Gender X Age X Type X Movement Amplitude X Block (of trials) univariate analysis of variance with repeated measures on the last two factors. This analysis facilitated the comparison of the effects of the three major independent variables upon task execution. Following the main analysis, specific differences were isolated using the Scheffe post-hoc technique.

Performance Accuracy

There is some controversy concerning the appropriateness of statistical measures employed to assess error event data. Some researchers prefer to use Chi-squared tests while others prefer an Analysis of Variance or a Log-Linear approach. The protocol established by those who designed the apparatus was adhered to in the present study (Buck, et al., 1982). In keeping with the precedent set by these motor behaviorists, the influence of the aforementioned variables on the accuracy of decision-making, was assessed by subjecting the number of response errors committed during each trial to a series of Chi-squared tests. For example, the error data for males was compared to that of females. The error data for Type A subjects was compared to that of Type B subjects. The number of errors made by each of the age groups was then compared to each of the other age groups. Recall that to reduce the risk of confusing, and subsequently analysing true cognitive errors with hand tremors, or unintentional hand movements, a 15 msec criterion was imposed on the error time data. This fidgeting was more of a problem for some of the subjects over 75 years of age, than for the subjects under that age.

Similarly, the extent to which age, cardiovascular behavioral profile, and gender influenced the accuracy of alignment execution was also analysed. These comparisons were performed by subjecting the number of overshoots incurred by each of the age groups; by each behavioral profile; and by each gender, respectively, to Chi-squared tests. Males were compared to females; each of the age groups to one another; and Type A profile to Type B profile, repeating those comparisons made for error rate. Differences in mean rates of errors and of overshoots, averaged across age, gender, and cardiovascular behavioral profile were observed across blocks of trials, and across levels of relevant within task difficulty. Unfortunately, these observations could not be statistically analysed without inflating the Type I error rate. Specifically, in the case of learning to reduce errors and overshoots across blocks of trials, the homoscedasticity or the independence of observations assumptions is violated. Unequal, and sometimes empty cells, prohibited the analysis of error rate across levels of directional probability; and of overshoot rate across levels of boundary distance (Gessaroli, 1985).

<u>Adaptation to Response Errors</u>

Finally, the compensatory adjustments subjects made to their reaction times following a response error were examined. Correct reaction times were subjected to a Gender X Age X Type X Previous Response Accuracy X Directional Probability X Block (of trials) univariate analysis of variance with repeated measures on the last three factors. The repeated measures technique allowed for the examination of the relative influence age, cardiovascular behavioral profile, and gender had on subjects' ability to learn to recover from their mistakes. One final note, data within 2.0 standard deviations of the mean was considered to be within "normal" limits, and the level of statistical significance has been operationally defined at 0.05 for this study.

CHAPTER FOUR

RESULTS AND DISCUSSION

For the purpose of the analysis, subjects were categorized according to cardiovascular behavioral profile. Being profiled as having a Type A behavior implies a certain predisposition to cardiovascular dysfunction, and so it follows that this tendency should eventually manifest itself. No Type A individuals of either gender, over the age of 75 years were identified in the present study. Therefore, comparisons of the influence of this behavioral variable (i.e., Type A versus Type B) on motor performance were restricted to the four youngest age groups, 55 to 74 years. Analyses for gender, and age, exclusive of behavioral profile were performed on all six age groups, 55 to 84 years, using only the Type B behavior subjects to determine if the group differences in performance measures existing among the younger age groups were maintained, or if they changed among older subjects. Each of the six specific indices of motor performance collected through the use of the tracometer will now be presented, in turn, under three sub-sections. The first of these two sub-sections pertains to the measures concerned with performance speed, and the second with performance accuracy. In the third sub-section the reaction times following a response error will be examined. Within each of these sub-sections, age, gender, and cardiovascular behavioral effects will be presented, respectively.

<u>Performance Speed Measures</u>

The distribution of scores for each of the performance speed measures, total response time, total response time by quintiles, correct reaction time and non-overshoot movement time were all within normal limits, operationally defined as 2.0 standard deviations from the mean (see Appendix A). A composite of the multivariate and univariate analyses of variance with repeated measures on performance speed measures is presented in Table 1. The complete versions of the two MANOVA tables concerned with speed measures may be found in Appendix B. The complete versions of the univariate ANOVA tables concerned with total response time, correct reaction time, and non-overshoot movement time are found in Appendicies C, D, and E, respectively.

None of the 3-way, 4-way, and 5-way multivariate interactions concerned with performance speed measures were significant (($p>.1$) (see Appendicies B-E)). A multivariate analysis of variance with repeated measures using only cardiovascular behavioral profile Type B subjects was also performed to accomodate the older age groups in which Type A behavior subjects had not been identified. The 3-way, 4-way, and 5-way multivariate interactions remained non-significant (see Appendicies B & C). These interactions will not be further elaborated upon because their respective multivariate F-values were estimated to be non-significant.

Table 1

Composite of Performance Speed Measures
Analysis (55 to 74 years)

Source	Performance Speed Measures: Multivariate Pillais Approx. F	Univariate Derived F: TRT	CRT	NO-OVMT
Age	3.27****	12.27****	6.47****	9.81****
Gender	5.95****	16.01****	4.67****	13.89****
Type	0.91	0.03	1.13	0.23
Task Complexity	N.A.	N.A.	250.46****	532.22****
Block (of trials)	12.93****	80.29****	70.47****	40.95****
Age X Gender	1.09	0.97	0.84	0.99
Age X Type	0.64	1.00	1.24	0.91
Age X Complx	N.A.	N.A.	0.44	2.93****
Age X Block	1.36	1.36	1.32	0.66
Gender X Type	1.46	1.16	0.74	0.00
Gender X Complx	N.A.	N.A.	0.90	2.56**
Gender X Block	3.17**	3.28**	3.37**	3.89**
Type X Complx	N.A.	N.A.	0.13	0.23
Type X Block	0.89	0.13	0.15	1.22
Complex X Block	N.A.	N.A.	3.00****	8.58****
Gen X Age X Type	0.65	0.40	0.33	0.10

Note:
TRT = Total Response Time
CRT = Correct Reaction Time
NO-OVMT = Non-Overshoot Movement Time
Type = Cardiovascular Behavioral Profile
Task Complexity = depicts effect of Directional Probability on CRT; and of Movement Amplitude on NO-OVMT
N.A. = Analysis not applicable
Gen = Gender; Complx = Task Complexity (as above)
Significance Level: * = $p<.05$ ** = $p<.025$
*** = $p<.01$ **** = $p<.001$

Total Response Time

From a descriptive point of view, younger subjects were faster than were older subjects, and males were faster than females. With respect to the inferential framework employed, the main effect of age was statistically significant ($p<.001$) in the aforementioned multivariate and univariate analyses. In reviewing the age effect, the data confirmed that younger subjects had significantly faster total response times than did older subjects consistent with previous literature (Welford, 1980). In Figure 4 the effects of age ($p<.001$) and of block ($p<.001$) on total response time are illustrated. Although the Age X Gender interaction was non-significant, with practice, the two oldest age groups appeared to improve (reduce) their total response times moreso than did the four youngest age groups. For all groups the most substantial improvement in total response time occurred within the first block of trials (see Figure 4). The difference in performance speed between genders was also statistically significant ($p<.001$) in both of the multivariate analyses of variance described earlier. Females were consistently, and significantly, slower than were males in their total response times. Both genders improved their performance significantly over the four blocks of trials ($p<.001$). Though the between-gender difference in total response time was significantly reduced, especially within the second block of trials, the females were never able to match or surpass the males (see Figure 5).

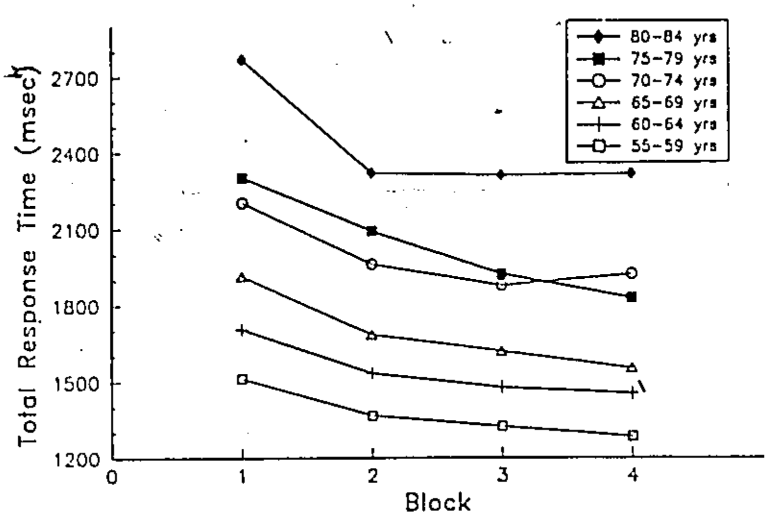

Figure 4
Total Response Time for Age X Block

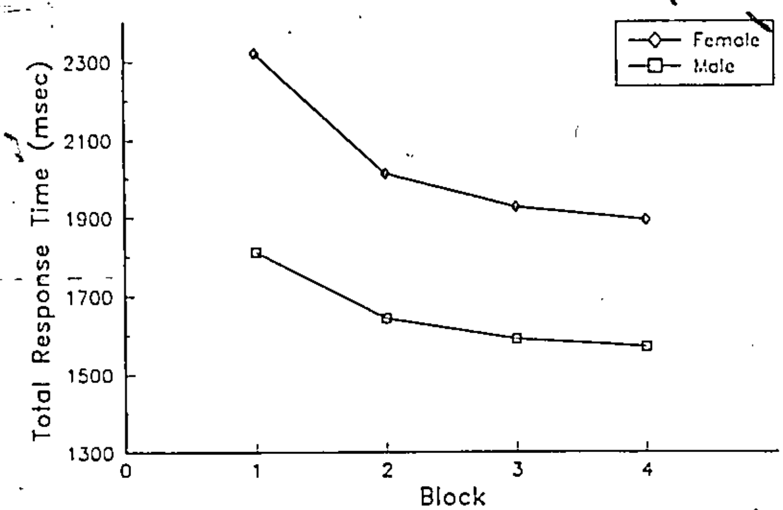

Figure 5
Total Response Times for Gender X Block

This between-gender difference on total response time was greater than that which was predicted (Botwinick & Storandt, 1967,1974; Botwinick & Thompson, 1966; Noble et al., 1964; Salthouse & Somberg, 1982). The difference between cardiovascular behavior profiles was less than predicted (see Table 2), contrasting earlier findings derived from research concerned with the contribution that predisposition to cardiovascular dysfunction makes to motor performance (Abrahams & Birren, 1973; Bortner & Rosenman, 1967; Speith, 1965). The cardiovascular behavioral profile Type A subjects were observed to be slower than were their Type B counterparts, but this difference was negligible and varied little with practice ($p > .1$), or with age (($p > .1$)(see Table 1 and Appendix B)). To avoid repetition and to enhance understanding, the possible reasons for this incongruence with previous research will be discussed in terms of those performance-speed measures that help to make up the total response time score.

Table 2

Mean Total Response Times (msec) for Type X Block

Type	Block 1	Block 2	Block 3	Block 4
A	1844	1645	1578	1560
(SD)	88.3	74.7	72.9	86.0
B	1815	1641	1566	1546
(SD)	64.3	53.8	52.0	51.9

Note: Type = Cardiovascular Behavioral Profile
(SD) = Standard Deviation

Total Response Time by Quintile

A summary of the two univariate analyses of variance, i.e., for the four youngest age groups including the cardiovascular behavioral profile comparisons, and for all six age groups exclusive of Type A behavior subjects, is presented in Table 3. The more complete version of these comparisons found in Appendix C, reveals that for Total Response Time X Quintiles none of the 3-way, 4-way, or 5-way interactions were significant.

Table 3

Summary of the Univariate ANOVAS for
Total Response Times (msec) X Quintile

Effect	Total Response Times X Quintiles	
	Ages 55 to 74 F values	Ages 55 to 84 F values
Age	12.24****	8.68****
Gender	15.98****	10.11****
Type	0.04	N.A.
Block (of Trials)	80.22****	93.94****
Quintile	3.44****	8.76****
Age X Gender	0.97	0.21
Age X Type	1.01	N.A.
Age X Block	1.35	3.00****
Age X Quintile	1.50	1.09
Gender X Type	1.19	N.A.
Gender X Block	3.26***	4.13****
Gender X Quintile	1.95	0.36
Type X Block	0.13	N.A.
Type X Quintile	0:99	N.A.
Block X Quintile	10.46****	7.77****

Note:
Type = Cardiovascular Behavioral Profile
N.A. = Analysis not applicable
Significance Level: * = $p<.05$ ** = $p<.025$
*** = $p<.01$ **** = $p<.001$

Separating the total response time into quintiles revealed that subjects exhibited their slowest, or largest, total response times in the first quintile, i.e., on the first presentation of the between-target movements. Perhaps the observed vacilation in total response speed across quintiles and blocks reflects the extent to which subjects were attending to, and were confident in their ability to execute the task. To elaborate on this point, perhaps at the beginning of the trial subjects were unfamiliar with the task of executing the between-target movements facing them and so they responded cautiously. On the second quintile subjects were more familiar with the task and were possibly more confident, and as a result reponded significantly faster ($p<.05$) than they had on the first quintile. Perhaps after incurring errors and overshoots, subjects were unable to improve their subsequent response speed on the third quintile ($p>.05$). Then if accuracy was more assured, subjects would have the confidence to significantly increase their response speed on the final two quintiles ($p<.05$). This acceleration and deceleration of total response times within trials is generally consistent across the four blocks of trials. Figure 6 depicts the Quintile X Block interaction ($p<.001$), in which subjects begin the first quintile of a block of trials with total response times faster than those observed at the conclusion of their previous block.

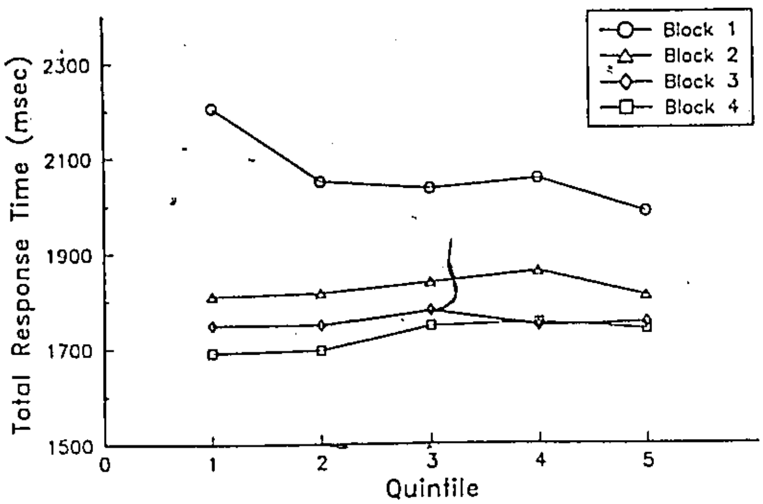

Figure 6
Total Response Times X Quintile X Block

In order to illustrate the origins of these fluctuations in total response time, the observed changes in reaction time scores, and in movement time scores will now be presented.

Correct Reaction Time

With respect to the cognitive aspect of total response time, correct reaction time scores also differed significantly between groups. There were twenty-six cases where no data was available at the 0.25 level of directional probability as measured by the instrument, creating unequal and sometimes empty cells. However, this does not imply that seniors are incapable of performing a pursuit tracking task. Admittedly, some subjects had more trouble executing their movements when target location was least certain, in a manner consistent with that reported in the literature (Birren, Riegel & Morrison, 1962; Welford, 1977), but most subjects readily adapted to changes in directional probability. In an effort to save the balance of the data concerned with the effect of directional probability on correct reaction times, only the complete data, from the 1.00, 0.75, and 0.50 levels of probability were used in the final analyses. All four levels are presented in the tables for the purpose of description. The distribution of the correct reaction time scores was within the normal limits established for this study (see Appendix A). A summary of the analysis is presented in Table 1 (see also Appendix B).

The results of the present study concur with earlier research concerned with age and reaction time (Kalish, 1975; Kline & Szafran, 1975; Rabbitt, 1977; Welford, 1978). A significant difference among age groups on correct reaction times was observed such that younger subjects had faster reaction times than did the older subjects ($p<.001$). However, fluctuations in the increases in correct reaction time with age were observed (see Table 4). Granted the Age X Gender interaction was not statistically significant, however, when one considers the overall performance of two particular age groups certain trends and questions arise. These fluctuations with age and with gender were not fully understood until a thorough review was made of the brief subject histories collected at the time of each subject's participation. Details regarding the personal activity levels of some of the subjects were uncovered. That is to say, the decrease noted in mean correct reaction times across the seventies may have been due to the 75 to 79 year old males, 80% of whom were Commissionaires. Their active participation in this work program may have been enough to counter the adverse effects of aging.

Table 4

Mean Correct Reaction Times (msec) for Gender X Age

Gender	Age Groups 55-59	60-64	65-69	70-74	75-79	80-84
Female	409	493	479	532	616	739
(SD)	7.6	11.2	7.6	12.1	26.3	25.8
Male	398	397	422	514	512	546
(SD)	5.7	5.8	6.3	10.3	9.2	13.7

Note: (SD) = Standard Deviation

As a result, these male Commissionaires were able to bias the mean correct reaction time score for their age group enough to actually demonstrate a faster mean score than subjects five years younger. Admittedly, it is difficult to distinguish whether the rigours of working as a Commissionaire keeps people active and alert, or whether those who react more quickly to begin with are more apt to gravitate towards positions requiring their continued dedication and attention, but it does speak favorably for the Law of Disuse. Similarly, females in the 55 to 59 year age group were still employed while 60% of the females in the 60 to 64 year age group had not been employed outside the home in over 40 years. This "inactivity" combined with their advanced age may have accounted for the increase in correct reaction times observed between these two female age groups which did not appear between their same-aged male counterparts. Neither the males nor the females differed appreciably in reaction times across their sixties. The faster correct reaction times exhibited by the 65 to 69 year old females over the 60 to 64 year old females, may have been the result of the "Professional Volunteers" in the older group. Sixty percent of the females aged 65 to 69 years were very actively involved in community service work. Some of these subjects in their late sixties were so busy that they had difficulty fitting their participation in this study into their schedule. So it would seem that seniors engaged in activities requiring their continued attention and decision-making, react more quickly than their less active contemporaries. This finding concurs with earlier researchers (Spirduso, 1975, 1985; Spirduso & Clifford, 1978) who suggested that those persons who continue to "demand of themselves" maintain their ability to challenge and achieve psychomotor goals. For females after age 70, a slowing in performance speed was observed with age consistent with that found in the literature (Kalish, 1975; Kline & Szafran, 1975; Rabbitt, 1977; Welford, 1978).

Descriptively speaking, males had consistently faster correct reaction times than had females of the same age. Statistically, the main effect for gender was significant (($p<.001$)(see Figure 7)). This latter finding contradicts the earlier work by Salthouse and Somberg (1982) and Botwinick and

Storandt (1967;1974) who found the gender effect to be non-significant.

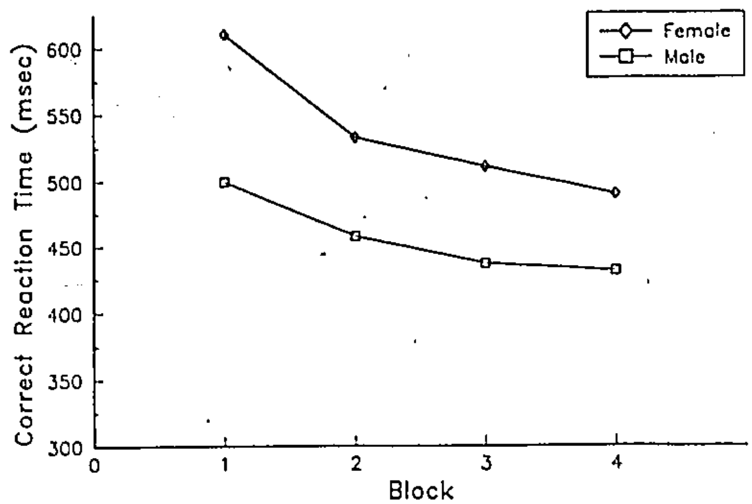

Figure 7
Correct Reaction Times for Gender X Block

The main effect for block was significant as all subjects markedly improved their correct reaction times with practice ($p<.001$). The Gender X Block interaction was also significant ($p<.025$) such that the females made dramatically more improvement than did the males, especially within the second block of trials (according to a Scheffe post-hoc analysis). Initially, the males exhibited markedly faster reaction times than did the females ($p<.001$). But the females continued to reduce their correct reaction times with practice, while the males appeared to stop making any further gains by the end of the third block of trials. Apparently, the females gained significantly more from practice than did the males ($p<.025$). An extrapolation of this Gender X

Block interaction suggests that with practice females may eventually become as fast as, or faster than males in reacting to the stimulus onset. This supposition cannot actually be confirmed within the constraints of the present study because only eight trials were completed by each subject. Notwithstanding the reduction in correct reaction times over the four blocks of trials made by females, they were still slower in reacting to the response stimulus than were the males (see Figure 7). Females expressed their apprehension in having to perform the task to the experimenter far more often than did the males, although the exact number of persons who verbalized their anxiety is not known. In retrospect, subjects should have been asked how they felt about participating in the experiment, and a notation made of their perception. Perhaps their perceived stress in being a "subject" in a university experiment reduced their confidence in this novel situation. This notion concurs with the suggestion made by Arenberg & Robertson-Tchabo (1977), that testing situations sometimes push the elderly beyond their capacity for anxiety, thereby reducing their ability to perform. Although the elderly were encouraged to participate and to perform as best they could, perhaps more attention should have been paid to assuaging their fears about the tracometer. For example, some subjects were highly suspicious about the outcome of the test. They were sure that the results were being forwarded to the Ministry of Transport, and that their driver's license would be revoked. Almost no amount of persuading would convince them otherwise. For researchers and for educators the testing situation is a very familiar one. But to someone who has not been called upon to perform in a long, and sometimes a very long time, having one's every move scrutinized can be enormously stressful. Unless the researcher does not wish to include stress as a dependent variable by design, it should be carefully controlled. Recall that the largest between-gender difference in correct reaction times occurred during the first block of trials. It is then possible that a confidence-related effect on performance may underlie some of the observed gender differences in performance speed.

With respect to their correct reaction time scores, the Type A behavior subjects were not siginificantly (p>.1) slower than were their Type B contemporaries ,(see Table 5). This between-profile difference did not vary appreciably across blocks of trials (p>.1), or with directional probability (p>.1). The remarkable similarity between the correct reaction times of the two cardiovascular behavioral profiles is demonstrated in Table 5. In addition to the non-significant main effect (p>.05), none of the interactions involving cardiovascular behavioral profile were significant. In earlier studies investigating the effects of cardiovascular behavioral profile on motor performance, Type A behavior subjects generally consisted of hospitalized patients with varying degrees of cardiovascular dysfunction (Bortner & Rosenman, 1967; Botwinick & Storandt, 1974; Speith, 1965). These subjects had then been matched with same-aged healthy volunteers, comprising the Type B behavior group. Conceivably, the reasons underlying the poorer performances of the Type A behavior group may have had more to do with their actual physical dysfunction than with their proposed personality profiles.

Table 5

Mean Correct Reaction Times (msec)
for Type X Directional Probability

Type	Directional Probability Level 1.00	0.75	0.50	0.25
A	404	468	489	501
(SD)	11.4	11.5	11.6	10.2
B	384	444	467	486
(SD)	5.8	6.1	6.2	6.8

Note: Type = Cardiovascular Behavioral Profile
(SD) = Standard Deviation

Concerning the decrements in motor performance associated with cardiac dysfunction, Bortner and Rosenman (1967) and Abrahams and Birren (1973) predicted that subjects classified as having a Type A behavior would have slower reaction times than would the Type B behavior subjects. These investigators concluded that this difference would exist even in the absence of the overt physical manifestations of the cardiac dysfunction, such that, "...perhaps psychomotor slowing existed prior to the acute onset of CHD [Coronary Heart Disease] and may be the consequence of psychobiological antecedents to the disease" (Abrahams & Birren, 1973, p.478). In light of the huge disparity between the findings of these early researchers and those of the present study, one has to wonder just how physically healthy the subjects in the earlier Type A behavior groups were. That Abrahams and Birren (1973, p.478) used the phrase, "...prior to the acute onset of CHD...", may have allowed for the inclusion of subjects suffering from hypertension or subclinical oxygen insufficiency, prior to their being diagnosed as cardiac patients. Similarly, if the groups were not as behaviorally distinct in the present study as they have been in the past, perhaps the nonconcurrence with the experimental findings reported by these earlier studies (Abrahams & Birren, 1967, 1973; Bortner & Rosenman, 1967; Speith, 1965), could be more easily explained. That is to say, perhaps the subjects comprising earlier Type A profile groups may have been further along the scale as a Type A (ACCELERATED), and the Type B profile groups further along in the opposite direction on the scale, towards the Type B behavior (BRAKES), than the subjects identified in the present experiment. However, the subjects were by no means "clustered together" on the cardiovascular profile scale, and the performance of the two behaviorally profiled groups was so remarkably similar on all of the measures in the present study, that this latter argument seems improbable. The strict adherence to selecting healthy subjects in the present experiment may have controlled for the inflation of the Type A behavior influence by screening out subjects with both chronic and acute cardiovascul and cerebrovascular dysfunction. It may also be conjectured that the distinction between these two behavioral profiles dissipates with age, except that the Type X Age interaction was non-significant on performance speed measures ($p>.1$). Perhaps the identification of persons predisposed to cardiovascular disease by their responses to the Jenkins Activity Survey is not as reliable for seniors, who respond in retrospect to some of the questions, as it is for younger persons who respond to situations in which they are currently involved. For whatever reason, subject categorization by cardiovascular behavioral profile did not appear to be a valid predictor of motor performance speed, and as will be discussed later, response accuracy, in this experiment for healthy males and females aged 55 to 84 years. Evidently more research is necessary to isolate the exact origins of the alleged cardiac-related limitations on motor performance.

The main effect of directional probability on correct reaction time was significant ($p<.001$), such that subjects exhibited longer correct reaction times with decreasing levels of directional probability. For example, on the 1.00, 0.75, 0.50, and 0.25 levels of directional probability the mean correct reaction time scores averaged across age, gender, cardiovascular behavioral profile, and blocks, rose from 453, to 509, to 526, to 531 msec respectively. A more complete breakdown of the change in correct reaction time with directional probability is presented in Table 22 in Appendix D. The univariate Block X Complexity interaction was also significant ($p<.001$). Subjects not only improved their performance with practice, but that they improved more on the more predictable level of 1.00, than they did on the less predictable level of 0.50. Contrary to the previous findings of investigators examining the relationship between age, reaction time, and changes in target certainty (Birren, Riegel & Morrison, 1962; Welford, 1977), the older subjects in the present study incurred only insignificant ($p>.1$) increases in reaction time with decreasing levels of directional probability moreso than did the younger subjects.

As eluded to by Price, Fein and Feinberg (1980), a very different picture of age and motor performance develops when seniors are used as their own frame of reference, rather than when young university students are used. Perhaps the age differences in motor performance in general, reaction time specifically, are more subtle than were previously thought. Perhaps the lifestyle demands that the performer places upon himself or herself are more of a determinant of the cognitive ability to respond quickly, than is the age of the respondent alone. This would certainly support the physical activity research, which suggests that people "age" at different rates according to their level of physical fitness (Rabbitt, 1982; Spirduso, 1975, 1985; Spirduso & Clifford, 1978). The question of whether these demands have a similar maintenance, or practice effect on the execution of the task will now be pursued through the presentation of non-overshoot movement time data.

Non-Overshoot Movement Time

Generally, younger subjects had faster movement times than did older subjects, and males were faster than were females. A summary of this multivariate analysis of variance with repeated measures has already been presented in Table 1 (see also Appendix B). The main effect for age was statistically significant ($p<.001$), such that younger subjects generally had faster non-overshoot movement times than their older counterparts (see Table 6). Changes in the mean non-overshoot movement time scores with age were similar to those found in correct reaction time scores. Significant slowing in movement speed was observed between the 60 to 69 year age groups and the 70 to 79 year age groups ($p<.05$). As before, the Commissionaires in the 75 to 79 year age group appeared to bias their age group non-overshoot movement time mean sufficiently to demonstrate an improvement over the mean score of the males in the 70 to 74 year age group. Descriptively speaking, the females increased their non-overshoot movement times consistently with age. Unlike reaction time means no "pseudo-plateau" between the mean movement times of females in their sixties was observed. This suggests that although the 65 to 69 year old female "Volunteers" had faster correct reaction times than the less active 60 to 64 year olds, the stimulation the "Volunteers" derived from their activity did not seem to influence the movement execution speed of their motor performance. The motor performance of the Commissionaires and of the Volunteers is brought to the attention of the reader as a depiction of the influence of active lifestyles rather than it is of the Age X Gender interaction.

Irrespective of age, males had significantly faster non-overshoot movement times than did females, regardless of the movement amplitude, and across all four blocks of trials ($p<.025$). Both genders significantly improved their non-overshoot movement times over blocks of trials ($p<.001$).

Table 6

Mean Non-Overshoot Movement Times (msec)
for Gender X Age

Gender	Age Group 55-59	60-64	65-69	70-74	75-79	80-84
Female	998	1179	1361	1475	1624	1714
(SD)	20.8	27.4	36.5	38.3	69.8	44.7
Male	945	969	1035	1268	1236	1453
(SD)	24.7	20.8	28.3	34.4	34.7	39.7

Note: (SD) = Standard Deviation

Once again, the largest difference between the two genders occurred during the first block of trials, when subjects are thought to be familiarizing themselves with the particulars of the task. Again the females made significantly more improvement after the first block of trials than did the males ($p<.025$) in a manner similar to the observed changes in correct reaction time scores across blocks. Even though females made improvements twice that of the males, this continued improvement in the third and fourth blocks was statistically non-significant according to the Scheffe post-hoc analysis (($p>.05$)(see Table 7)). As with correct reaction time, this significant Gender X Block interaction ($p<.025$), suggests that with more practice the females may eventually increase their movement speed to that of the males.

Table 7

Mean Non-Overshoot Movement Times (msec) for Gender X Block

Gender	Ages	Block 1	2	3	4
Female	(55-74)	1542	1392	1332	1301
(SD)		45.7	39.9	31.7	31.7
Male	(55-74)	1210	1147	1131	1116
(SD)		29.7	27.6	26.8	27.5
Female	(55-84)	1378	1241	1211	1183
(SD)		41.1	33.0	30.6	30.8
Male	(55-84)	1119	1050	1029	1019
(SD)		30.6	28.5	27.7	29.6

Note: (SD) = Standard Deviation

However, it is difficult to predict whether, or indeed when, females might actually match or surpass males on either measures of reaction time or movement time. Without wishing to underestimate the significance of the Gender X Block interaction on performance speed, it must be realized that, in time, regardless of their gender, subjects discontinue improving on the task because of boredom and/or physical fatigue. Recall that in earlier investigations of gender differences on motor performance tasks no Gender X Block interaction was recorded (Botwinick & Storandt, 1967, 1974; Noble et al., 1964; Salthouse & Somberg, 1982). In addition, gender effects were thought to be associated with decision-making moreso than with execution (Botwinick & Thompson, 1966; Welford, 1980). Perhaps the initial novelty of the task exacerbated gender-differences on performance speed measures. Since significant gender effects were observed in both the reaction time and the movement time measures, particularly within the first block of trials, more research into gender-related decrements in motor performance appears necessary to help identify, and perhaps explain their occurence.

Non-overshoot movement times increased significantly with increases in the movement amplitude to be covered ($p<.001$) consistent with earlier tracometer use (Buck et al, 1981). Post-hoc analysis detected that subjects over 65 years of age had disproportionately longer non-overshoot movement times on the longer distances ($p<.05$) than did their younger counterparts (see Table 8).

Table 8

Mean Non-Overshoot Movement Times (msec) for All Ages X Movement Amplitude

Age	Movement Amplitude (mm) 41	82	123	164
55-59	690	873	1075	1249
(SD)	12.9	17.5	23.7	30.8
60-64	764	964	1182	1384
(SD)	16.6	21.3	24.3	35.6
65-69	841	1088	1320	1544
(SD)	23.9	34.4	45.8	51.1
70-74	966	1249	1509	1762
(SD)	25.6	34.8	45.7	52.7
75-79	1023	1315	1569	1814
(SD)	46.8	66.8	75.7	98.1
80-84	1170	1474	1747	1942
(SD)	40.9	50.5	56.4	59.9

Note: (SD) = Standard Deviation

At first glance, the cardiovascular Type A behavior subjects appeared to have repeatedly shorter non-overshoot movement times than the Type B behavior subjects. The difference between these two profiles did not change appreciably with increasing movement amplitude and at no time was the difference between cardiovascular behavioral profiles statistically significant ($p>.05$). An example of their similarity and the extent to which movement speed varied directly with movement amplitude is represented in Table 9.

Table 9

Mean Non-Overshoot Movement Times (msec)
for Type X Movement Amplitude

Type	Movement Amplitude (mm) 41	82	123	164
A	809	1034	1253	1476
(SD)	16.7	21.3	27.7	34.6
B	821	1053	1290	1494
(SD)	16.4	24.0	29.8	34.0

Note: Type = Cardiovascular Behavioral Profile
(SD) = Standard Deviation

Significantly more improvement in movement speed was made on the longer movement amplitudes, 123 and 164mm, than on the shorter between-target movements, 41 and 82mm ($p<.05$). Although subjects improved steadily across blocks, significantly more improvement in movement speed was made during the second block of trials ($p<.05$) than during the last block of trials (see Table 10). Both of these latter comparisons were performed using Scheffe post-hoc analyses.

Table 10

Mean Non-Overshoot Movement Times (msec)
for Block X Movement Amplitude

Block	Movement Amplitude (mm) 41	82	123	164
1	960	1253	1534	1757
(SD)	32.1	44.2	54.4	62.4
2	911	1163	1388	1617
(SD)	30.1	40.3	45.5	55.4
3	890	1132	1358	1546
(SD)	26.3	35.4	37.4	43.5
4	874	1095	1322	1543
(SD)	25.9	31.4	38.2	46.2

Note: (SD) = Standard Deviation

Having presented the data pertaining to performance speed measures those measures concerned with performance accuracy will now be presented.

Performance Accuracy Measures

Subjects of all ages, 55 to 84 years, displayed a degree of movement accuracy consistent with that of the earlier literature pertaining to cautiousness (Birren, Woods, & Williams, 1980; Bosser, 1982; Botwinick, 1978). For example, there was an exceptionally large number, 604 of a possible 960 subject-trial cases (120 subjects X 8 trials), for which there was no overshoot movement time score. The absence of these scores precluded any meaningful presentation or analysis of this movement time measure. The prevalence of the completed trials with no movement overshoots suggests that seniors in this study were able to achieve accuracy in their movements. Whether or not the subjects in the present study were exercising caution, and actually traded speed for accuracy is not readily discernable. Instead, through the examination of both performance speed and accuracy variables, one may only tentatively interpret their tacit intentions. To be certain of a trade off, subjects would have to have been questioned as to whether they had been sacrificing speed for accuracy, or vice-versa, at the time of their testing. Their recollection of the task and of their performance would probably then have been the most vivid. The infrequency (356 cases) with which movement overshoots occurred indirectly attests to the accuracy of the performances by these subjects. Two more direct measures of performance accuracy assessed in the present study include the error rate and the overshoot rate.

Error Rate

When examining the measures of performance accuracy, error rate and overshoot rate observations were measured on a nominal scale, and therefore, parametric statistical procedures were considered inappropriate. The error data was transformed to nominal values and averaged across probability levels and across blocks of trials. From this data the median score of 26.4% errors was established. In the Chi-Squared analysis any score less than the respective median was considered a low score. Any rate greater than the respective median was considered a high score. This analysis detected that those subjects aged 55 to 59, 65 to 69, and 75 to 79 years of age, did not differ significantly in response accuracy (p>.05); and subjects aged 60 to 64, 70 to 74, and 80 to 84 years were not dissimilar in their error rates (p>.05). As determined by the Chi-squared analysis: (1) the first, third, and fifth age groups made significantly fewer errors than the second, fourth, and sixth age groups (p<.05); (2) that at no age was the difference in error rates between genders statistically significant (p>.05); and (3) the difference in error rates between the cardiovascular behavioral profiles was not statistically significant (p>.05).

Table 11

Percentage of Errors for Gender X Age

Gender	Age Groups 55-59	60-64	65-69	70-74	75-79	80-84	Mean
Female	22.5	27.6	20.9	28.4	26.9	30.3	26.1
(SD)	17.7	17.0	15.8	18.7	16.6	16.3	
Male	24.9	27.2	30.2	27.3	26.0	31.4	27.8
(SD)	16.5	18.8	20.3	15.2	17.0	17.6	
(MEAN)	(23.7)	(27.4)	(25.6)	(27.9)	(26.5)	(30.9)	(27.0)

Note: (SD) = Standard Deviation

The youngest subjects generally committed fewer errors (mean=23.7%) than did the oldest subjects ((mean=30.9%)(see Table 11)). That error rate increased with age supports the earlier work on age and the commission of errors (Farkas & Hoyer, 1980; Hartley, Harker & Walsh, 1980; Rabbitt, 1977; Rabbitt & Birren, 1967). Perhaps the non-illuminated lights on the display, occassional voices in the hallway, or outside traffic noises distracted the older performers in the present study. Combined with their slower rate of processing visual stimuli, and greater dependence on anticipation of stimulus information, performance accuracy was expected to decrease with age. An age-related decrease in accuracy was evident in the present study only until the seventies, after which subjects improved their movement accuracy. The notion that the elderly are slower and less accurate than their younger counterparts is not new. Calhoun and Hutchison (1981), Herrick (1983), and McPherson (1983), all reported that in response to performance speed decrements, the elderly often employ compensatory strategies such as caution and anticipation. As suggested by the review of literature, cautiousness is now interpreted as a deliberate adaptation to neuro-biological changes. One might conclude that while those in their seventies seem to be successful at reducing their error rates, subjects in their eighties, perhaps because of their alleged increased dependence on anticipation of the target location, should make more errors than should their younger counterparts.

Although the gender effect was not significant, it was interesting to note that overall male subjects committed more errors (mean=27.8%) than did female subjects (mean=26.1%). This similarity in gender accuracy supports the earlier work by Salthouse and Somberg (1982) and Botwinick and Storandt (1974) who suggested that the difference in performance accuracy between males and females would be non-significant. However, the results of these earlier studies indicated that females would make more errors than would males. Possible explanations for this apparent lack of congruence with the previous literatue could be: (1) the gender of the experimenter in each of the studies. Subjects, in particular females, have been reported to perform better when a same-sex experimenter has conducted the test (Williams, 1977; 1979); and (2) the "Volunteers". The largest between-gender difference in error rate occurred in the 65 to 69 year age groups (see Table 11). The performance accuracy displayed by the female "Volunteers" in this age group was superior to that of all of the other age groups in this study, regardless of gender and is largely responsible for the observed differences in mean error rate between genders. Table 11 represents the apparent erratic relationship between age, gender, and error rate found in the present study. Recall that no statistical measure was employed to assess the influence of an Age X Gender interaction. This unusual trend may partially be a function of the lifestyles of some of the subjects, as described earlier. One might suspect that the mean error rate averaged across blocks of trials and levels of directional probablity for subjects in the 65 to 69 year age group might have been significantly higher (mean approx.=27.7%) had the female "Volunteers" in the group not been so accurate.

From a descriptive viewpoint, that females in the 75 to 79 year age group had error rates smaller than females in their sixties suggests that these seventy year old females have attempted and successfully achieved greater accuracy in spite of their age. Combined with the smaller error rates of the male Commissionaires in this age group, the mean error rate for the 75 to 79 year age group was smaller than that of subjects five years younger. That these older subjects were more accurate yet slower than their younger counterparts (see Tables 4, 7, and 11), suggests that speed may have been sacrificed in an effort to achieve this accuracy. Yet the success enjoyed by the 75 to 79 year old subjects in movement accuracy is not shared by their older counterparts. Both males and females in the 80 to 84 year age group appeared to be less efficient than subjects in any of the other age groups, such that the 80 to 84 year olds not only had the slowest performance speed scores but they also incurred the highest error rates of all of the subjects. If, as the literature suggests, that with age one attempts to achieve greater accuracy even at the expense of speed, the 80 to 84 year old subjects in the present study seemed less able to achieve this mandate than were the males and the females in the 75 to 79 year old age group.

The Chi-Squared test performed on the error score data revealed that the difference between the accuracy displayed by the two cardiovascular behavioral profiles was not significant ($p>.05$). This result is congruous with the other measures of performance analyzed in the present study, but it refutes the finding of Speith (1965), and of Abrahams and Birren (1973) who reported that Type A behavior subjects would make significantly more errors than would Type B behavior subjects. Differences in error rates did occur elsewhere. For example, differences in error rate averaged across age groups, gender, and cardiovascular behavioral profile, however minimal, were observed between the four blocks of trials (see Table 12), and between the four probability levels (see Table 13). As was mentioned in the presentation of the design and analysis, problems with violations of the homoscedasticity or independence of observations, unequal and sometimes empty cells precluded the statistical analysis of error rate across blocks of trials or across levels of probability respectively.

It is neither the author's intention to undermine the importance of these statistical considerations, nor to overestimate the significance of these observations. However, as suggested by Pachella (1974), small differences in accuracy may reflect large differences in the subject's intentions. Changes in accuracy rates across blocks and directional probability are described for the reader simply to illustrate the similarity between the patterns of performance accuracy found in the present study and those found in earlier research. The mean error rates for all six age groups declined from 29.2% in block 1, to 27.4% in block 2, to 26.5% in block 3, to 26.1% in block 4. This would seem to indicate that overall, subjects were capable of at least minimally improving their performance accuracy with practice.

The mean error rate data shows that males made more errors than did females across all four blocks of trials although the error rates for each gender were virtually identical in the first two blocks (see Table 12). Small gender differences appeared in the third and fourth block, with the largest of these minor differences occurring in the last block. In addition, the mean error rates for the four youngest age groups, found on Table 12, and those for all six age groups, quoted above in the text are very similar. Apparently, all of the subjects regardless of age or gender learned to reduce the number of errors they committed with practice and with increases in directional probability. Both of these observations concur with earlier research designs which used the number of errors committed as a measure of performance accuracy (Rabbitt & Birren, 1967; Rabbitt & Rogers, 1977). To illustrate the ability of subjects to use directional probability to reduce their error rates across blocks of trials, Table 23, found in Appendix F, was constructed. The exceptions to this improvement with practice occur on both the easiest or most probable, and on the hardest or least probable, levels of directional probability where error rates are somewhat erratic. Chi-squared analysis revealed no significant difference between the performance accuracy of the cardiovascular behavioral profiles ($p>.05$). Their similarity in terms of error rate across levels of directional probability are displayed in Table 13.

Table 12

Percentage of Errors for Gender X Block
(Ages 55 to 74)

Gender	Block 1	2	3	4
Female	28.8	26.7	25.0	24.9
(SD)	1.7	1.7	1.8	1.7
Male	29.0	27.6	28.0	26.7
(SD)	1.7	1.6	1.9	1.9

Note: (SD) = Standard Deviation

Table 13

Percentage of Errors for Type
X Directional Probability

Type	Directional Probability 1.00	0.75	0.50	0.25
A	3.0	15.8	36.4	51.3
(SD)	3.6	6.7	9.5	15.3
B	3.0	15.5	36.1	51.0
(SD)	3.0	7.2	9.6	15.2

Note: Type = Cardiovascular Behavioral Profile
(SD) = Standard Deviation

Overshoot Rate

Just as error rate illustrates the frequency with which subjects "start off in the wrong direction", overshoot rate accounts for the number of times subjects pass over the far side of the target they are attempting to align with the pointer (see Figure 3). Just as correct reaction time and error rate vary with directional probability, overshoot rate varies with the dimension of boundary distance (Buck, 1982; Buck, et al., 1981).

While the number of overshoots can be determined using the tracometer, the actual point in time when the correction was initiated cannot. Descriptively speaking, and as represented by Table 14, changes in overshoot rate with age and with gender were erratic. Females made fewer overshoots than did males until age 70, after which, females made more overshoots than their male counterparts. By age 80 the two genders are virtually equal in the number of overshoots they incurred. Females also made more overshoots with increasing age, until 70 years of age, after which their overshoot rates reduced with age. The data for males denotes an erratic relationship between age and overshoot rate (see Table 14). Overshoots were measured on a nominal scale. The overshoot data for each subject was averaged across blocks of trials, and across boundary distances and then submitted to a series of Chi-Squared Tests. The results of these tests demonstrated significant differences between age groups ($p<.05$), but not between genders ($p>.05$), or between cardiovascular behavioral profiles ($p>.05$).

Table 14

Percentage of Overshoots for Gender X Age

Gender	Age Groups 55-59	60-64	65-69	70-74	75-79	80-84	(Mean)
Female	22.5	22.7	23.2	27.4	26.4	25.0	24.5
(SD)	1.2	1.2	1.0	1.5	1.3	1.4	
Male	25.2	23.3	32.0	26.6	21.6	25.4	25.7
(SD)	1.3	1.5	1.6	1.5	1.6	1.4	
(Mean)	(23.9)	(23.1)	(27.6)	(26.8)	(24.2)	(25.4)	(25.1)

Note: (SD) = Standard Deviation

Once again the performance of the 65 to 69 year old female "Volunteers", and the 75 to 79 year old male Commissionaires was superior to that of their respective contemporaries. That females were found to be more accurate than males opposes the results of earlier gender-accuracy research (Botwinick & Storandt, 1974; Salthouse & Somberg, 1982). That gender differences did not dissipate with practice (see Table 23, found in Appendix F) is consistent with earlier researchers (Botwinick & Thompson, 1966; Noble et al., 1966; Welford, 1980). The largest differences in overshoot rate between the genders of the same age occurred between the 65 to 69 year olds, where the active female "Volunteers" made fewer overshoots or movement inaccuracies than did their less active male contemporaries. As with non-overshoot movement time, the apparently superior performance of these females on movement control measures was not enough to significantly offset the effects of aging. Conversely, the overshoot rates achieved by the male Commissionaires did significantly ($p<.05$) alter the mean score for both genders in the 75 to 79 year age group reaffirming the notion that continued decision making and use of attentional abilities helps to maintain motor performance speed and accuracy. The Law of Disuse may also indirectly help to explain why the males in the 65 to 69 year group made so many errors and overshoots. Perhaps the stress of retirement, combined with the disengagement from activities requiring their continued attention and utilization of time restricted decision-making abilities, resulted in preservation of their performance speed at the expense of their accuracy. The decline in overshoot rate between the 70 to 74 year age group and the 75 to 79 year age group again draws attention to the likelihood that the more elderly subject is attempting to be accurate. Unlike error rate, subjects in the 80 to 84 year age group were able to maintain overshoot rates similar to those subjects ten years younger. It might then be surmized that the increase in mean error and overshoot rates between the seventy- and the eighty-year old subjects may have more to do with the superior performance of the very active 75 to 79 year olds than with the inferior performance of the more sedate 80 to 84 year olds. Perhaps the erratic change in the generation rate of response inaccuracies with age observed in the present study is an important link in explaining why some researchers have found a significant difference in response accuracy with age, and some have not. Consequently, the observed vacillation of error rate, and overshoot rate with age supports the utility of grouping subjects by small age spans when assessing the motor abilities of the elderly and the delineation of subjects on the basis of their active versus inactive lifestyle. This vacilation in performance accuracy measures also seems to support Welford's (1979) contention that aging may have a more detrimental effect on the cognitive aspect of movement accuracy, as depicted by changes in error rate, than it does on the execution of the movement, as represented by changes in the overshoot rate.

Similar to the learning effect observed in error rates, subjects reduced their mean overshoot rates across the four blocks of trials. The difference betwen the mean overshoot rate of males (25.7%) and that of females (24.5%) was not significant (see Tables 14 & 15). The largest difference between mean gender overshoot rates appeared in the first block of trials where the task was still relatively novel for each group. It is interesting that in the first block of trials males had significantly faster correct reaction times ($p<.001$) and non-overshoot movement times ($p<.001$) than did females. During the same period, the error rates and the overshoot rates of each gender were not significantly different ($p>.05$). Had the between-gender differences in accuracy measures been significant there might be justification to suggest that the overall performance of the males parallels that of subjects who sacrifice accuracy for speed. This would be particularly appropriate for novel situations where self-confidence is often reflected in performance. As has been described earlier, on all of the measures taken in this study the largest between gender differences seem to occur during the initial block of trials where subjects begin to become familiar with the task. Males are thought to be more confident than are females (Williams, 1977; 1979), hence, males may have been less anxious when first faced with the pursuit tracking task. While most of the males had driven motor vehicles (cars, tractors, etc.) several of the older females had no prior driving experience. So initially, during the first few trials the steering aspect of the tracometer may have seemed more familiar to the males than it did to a number of the females. In retrospect, noting the exact number of those who had never driven a motor vehicle may have been of use in explaining the results concerning gender differences. Having an indirect steering mechanism did not make the task quite as novel for both genders as was anticipated.

Table 15

Percentage of Overshoots for Gender X Block

Gender	Block 1	2	3	4
Female	25.5	24.6	23.8	24.4
(SD)	1.1	1.0	1.1	1.1
Male	30.1	25.5	23.5	23.6
(SD)	1.4	1.2	1.1	1.2
(Mean)	(27.7)	(24.9)	(24.1)	(23.9)

Note: (SD) = Standard Deviation

In a duplication of their error rates, and as predicted, Type A subjects made more overshoots than did their Type B contemporaries (see Table 16). Again Chi-squared analysis of this profile-related difference in performance accuracy proved to be non-significant (p>.05). From a descriptive point of view, the incidence of overshoots varied with boundary distance, consistent with the earlier findings of Buck (1976). These noteworthy changes in overshoot rate with boundary distance will be presented. As before, descriptive observations are made merely to draw a parallel between the findings of the present study and those of earlier researchers concerned with aging and the effects of practice and confidence on task execution.

Table 16

Percentage of Overshoots for Type X Boundary Distance

Type	Boundary Distance 1	2	3	4
A	14.2	22.0	29.4	36.3
(SD)	1.0	1.1	1.3	1.4
B	14.0	21.6	28.7	34.9
(SD)	1.0	1.1	1.3	1.6
(Mean)	(14.1)	(21.8)	(29.1)	(35.6)

Note: Type = Cardiovascular Behavioral Profile
(SD) = Standard Deviation

Adaptation to Response Errors

To examine the adaptations made by subjects to response errors, reaction times were categorized according to whether the previous response was correct (without error) or incorrect (with error). For a summary of the results concerned with adaptations made to reaction times following a response error consult Table 17. This analysis revealed significant differences for age ($p<.001$), merely replicating those found for correct reaction times discussed earlier. While the reaction times did differ significantly among age groups ($p<.001$) it was not due to the correctness of the previous response. Neither the Age X Previous Response Correctness ($p>.1$), nor the Age X Block interactions were significant ($p>.1$). Consequently, older subjects did not slow their responses significantly more than, or for a longer period of time after an error than did the younger subjects in the present study contrary to the results of earlier research (Rabbitt & Vyas, 1970; Welford, 1980). Based upon this finding it may be suggested that older subjects were no less adroit at recovering from the commission of an error than were younger subjects. By virtue of the physiological and visual restrictions imposed upon subject selection, the subjects in the present study were perhaps more "healthy" than those subjects in Rabbitt & Vyas' (1970) study. Hence, good health may be a better indicator of functional ability than chronological age alone.

Table 17

Mean Correct Reaction Times (msec) Following An Error
For Age X Directional Probability

Age	Previous Response	Directional Probability 1.00	0.75	0.50	0.25
55-59	Correct	342	403	413	449
	Incorrect	337	403	433	444
60-64	Correct	383	442	457	494
	Incorrect	380	445	481	479
65-69	Correct	387	445	473	491
	Incorrect	384	451	483	504
70-74	Correct	466	530	544	541
	Incorrect	470	540	541	556
75-79	Correct	522	563	572	596
	Incorrect	515	573	562	614
80-84	Correct	627	670	660	614
	Incorrect	615	665	606	678

Although females appeared to slow their reaction times following an incorrect response (mean=478 msec) moreso than did males (mean=431 msec), this difference was statistically non-significant (p>.1). Rabbitt (1979), and Rabbitt and Rogers (1977) suggest that after detecting an error subjects slow their subsequent responses to a speed with which they feel comfortable, where they are confident that accuracy is more probable. If, as has been suggested that females have lower self-confidence to begin with (Williams, 1977; 1979), then making mistakes should potentially have been more grave, or of more consequence to females than it was to males. Hence, females were expected to slow their subsequent responses more than were males. This "over-reaction" to response errors could not be supported in the present study.

Table 18

Mean Correct Reaction Times (msec) Following An Error For Gender X Directional Probability

Previous Response	Gender	Directional Probability 1.00	0.75	0.50	0.25
Correct	Female	413	478	495	515
(SD)		9.8	9.8	9.5	10.3
	Male	376	432	449	472
(SD)		7.3	7.9	8.1	7.3
Incorrect	Female	415	481	517	526
(SD)		12.1	11.5	21.3	13.9
	Male	371	439	455	471
(SD)		7.8	9.7	11.7	11.6

Note: (SD) = Standard Deviation

Similarly, the Type A behavior profile did not slow their reaction times following an incorrect response (mean=468 msec) significantly ($p>.1$) moreso than did the Type B behavior profile ((mean=445 msec)(see Table 19)). Had the incidence of errors and overshoots been significantly different between these two profiles, perhaps their reaction times following a response error might also have been more diverse. To date, none of the literature reviewed has discussed the influence of either gender or cardiovascular behavioral profile on the reaction times of responses following an error. So observations concerning the influence of these two independent variables on the ability to adapt to, or recover from response errors are believed to be unique.

Table 19

Mean Correct Reaction Times (msec) Following An Error For Type X Directional Probability

Type	Directional Probability 1.00	0.75	0.50	0.25
A	404	470	493	506
(SD)	12.1	12.2	15.5	16.2
B	383	445	464	486
(SD)	6.0	6.7	8.5	10.1

Note: Type = Cardiovascular Behavioral Profile
(SD) = Standard Deviation

All of the subjects reduced their correct reaction times significantly across blocks of trials regardless of the accuracy of the previous response ($p<.001$). According to the univariate ANOVA performed, reaction times of responses following a correct response were not significantly faster, than for responses following incorrect responses ($p>.1$). In addition, reaction times for incorrect responses were observed to be faster than for correct responses at the same probability level if the correctness of the previous response was the same (see Table 20). Evidently subjects did follow the predicted cyclical pattern of responding by systematically increasing their reaction times after having made an error on the previous response. However, the significance of the previous response correctness on subsequent reaction time was far less than what was predicted by earlier researchers (Rabbitt, 1979; Rabbitt & Rogers, 1977; Rabbitt & Vyas, 1970; Welford, 1980).

An increase in the F-value associated with the influence of the previous response correctness on subsequent reaction times was observed across probability levels (see Tables 18 & 19). Not all of the four probability levels could be analysed because of the absence of data in some of the 0.50 and 0.25 level cells. The absence of data may be a result of subjects intentionally slowing their responses to ensure accuracy on these less predictable, hence, more difficult alignments. At the 1.00 probability level where directional probability is most predictable, the influence that the previous response correctness has on subsequent reaction times was $F=0.03$ ($df=1,64$). This same effect was estimated to be $F=3.49$ ($df=1,64$) at the 0.75 level of directional probability. The reader must again be cautioned that neither of these F-values is significant ($p>.1$). But the change with increasing target location uncertainty is noteworthy, and raises the question as to whether the influence of previous response correctness may become statistically significant on less probable, 0.50 or 0.25, levels of the task. This possibility may account for the discrepancies between the results of the present study and those of earlier error research concerned with adaptations in reaction times following response errors. Rabbitt (1979), Rabbitt and Rogers (1977), and Rabbitt and Vyas (1970) all used choice reaction time tasks where directional probability was less certain than the 1.00 and 0.75 probability levels available for analysis in the present study, and the present study indicated a greater likelihood for the influence of the previous response correctness to be significant with increasing target uncertainty. Perhaps the results of the present study and those previously acquired through research are not so disimilar after all, but are merely indicative of varying degrees of the same issue.

Table 20

Mean Reaction Times (msec) for Correct and Incorrect Responses X Directional Probability

Previous Response	Present Response	Directional Probability 1.00	0.75	0.50	0.25
Correct	Correct	478	531	549	580
(SD)		9.5	9.2	10.4	11.0
Correct	Incorrect	390	491	496	475
(SD)		12.0	11.5	15.6	17.2
Incorrect	Correct	470	557	587	601
(SD)		11.0	10.5	9.0	10.3
Incorrect	Incorrect	515	537	543	501
(SD)		13.2	12.9	15.1	13.0

Note: (SD) = Standard Deviation

CHAPTER FIVE

Summary, Conclusions and Recommendations

Summary

The purpose of this study was to examine the performance of healthy seniors on a step-input pursuit tracking task in order to achieve a better understanding of the relative contributions age, gender, and cardiovascular behavioral profile make to the speed and accuracy of psychomotor responses. The hypotheses tested in this study were :

Related to Performance Speed:

(1) Younger subjects are significantly faster in performance speed measures than are older subjects.

(2) Male subjects are significantly faster in performance speed measures than are female subjects.

(3) Type B subjects are significantly faster in performance speed measures than are Type A subjects.

Related to Performance Accuracy:

(4) Younger subjects are significantly more accurate than are older subjects.

(5) Male subjects are significantly more accurate than are females subjects.

(6) Type B subjects are significantly more accurate than are Type A subjects.

Related to Adaptation to Response Errors:

(7) Correct reaction times immediately following a response error are significantly faster for younger subjects than for older subjects.

(8) Correct reaction times immediately following a response error are significantly faster for male subjects than for female subjects.

(9) Correct reaction times immediately following a response error are significantly faster for Type B subjects than for Type A subjects.

One hundred and twenty subjects ranging in age from 55 to 84 years voluntarily took part in this study. All of the subjects were questioned as to the state of their physical and visual health prior to their actual participation. Only those subjects who met the physical fitness and visual acuity standards outlined earlier (see p.75) were allowed to attempt the task. Subjects aged 55 to 84 years were categorized on the basis of their age and their gender. All of the subjects over 75 years of age were found to have a Type B behavioral profile. Therefore, all of the comparisons of cardiovascular behavioral profile (Type A vs. Type B) performance were limited to ~~those~~ subjects comprising the four youngest age goups (55 to 74 years). Each subject completed a series of eight trials on a subject-paced continuous pursuit tracking task. The National Research Council tracometer was employed to assess the reaction of subjects to a stimulus presentation and to the commission of an error. Inherent in the task, as fixed by the instrument, were varying aspects of directional probability (0.25, 0.50, 0.75, and 1.00), movement amplitude (41, 82, 123, 164mm), and boundary distance (1,2,3,4). Throughout the (100 light) trials each of the twenty between-target movements appeared five times in a randomized sequence. Subjects were also asked to complete the Jenkins Activity Survey which characterized the possible predisposition to coronary heart disease on a continuous profile scale (Jenkins, Zyzanski & Rosenman, 1969).

Whenever possible, subjects were tested individually and under ambient room lighting. All participants were encouraged by the experimenter to proceed as quickly and as accurately in their alignments. The control unit monitored the movement generated output from the tracking unit potentiometer and then transcribed it onto magnetic tape for future decoding.

For subjects aged 55 to 74 years of age, a Gender X Age X Type X Blocks (of trials) multivariate analysis of variance (MANOVA) with repeated measures on the last factor was performed on the performance speed data, including the total reponse time, the correct reaction time, and the non-overshoot movement time scores. Their total response time by quintile scores were subjected to a Gender X Age X Type X Quintile X Blocks (of trials) univariate analysis of variance (ANOVA) with repeated measures on the last two factors because the quintile breakdown of this measure could not be equitably accomodated by the MANOVA due to the manner in which tracometer data is coded. Similarly, to examine the effects of target location certainty on performance speed: (1) correct reaction time scores were subjected to a Gender X Age X Type X Directional Probability X Blocks (of trials) univariate analysis of variance with repeated measures on the last two factors; and (2) non-overshoot movement times were subjected to a Gender X Age X Type X Movement Amplitude X Blocks (of trials) univariate analysis of variance with repeated measures on the last two factors. Performance accuracy scores were calculated by error rate and overshoot rate. The data for each of these two measures was submitted to a series of Chi-Squared Tests. Finally, a Gender X Age X Type X Previous Response Accuracy X Directional Probability X Block (of trials) univariate analysis of variance with repeated measures on the last three factors was performed on the correct reaction times of those responses immediately following an error response. All of the aforementioned analyses were repeated exclusive of the Type variable for subjects aged 55-84 years.

Conolusions

A summary of the main findings related to the hypotheses is found on Table 21. In relation to the first three hypotheses, which are concerned with performance speed including total response time, total response time by quintile, correct reaction time and non-overshoot movement time, it was discovered that: younger subjects were generally significantly faster than were older subjects; males were generally significantly faster than were females; and the difference between the performance speed of

Type A and Type B cardiovascular behavioral profiled subjects was not significant.

Table 21

Summary of the Observed Between-Group Differences

Measure	Experimental Groups Age Groups	Genders	Types
Total Response Time	p<.001	p<.001	p>.1
Total Response Time by Quintile	p<.001	p<.001	p>.1
Correct Reaction Time	p<.001	p<.001	p>.1
Non-Overshoot Movement Time	p<.001	p<.001	p>.1
Error Rate	p<.05	p>.05	p>.05
Overshoot Rate	p<.05	p>.05	p>.05
Reaction Time Following a Response Error	p>.05	p>.1	p>.1

Note: Types = Cardiovascular Behavioral Profile

In relation to the fourth, fifth, and sixth hypotheses, which are concerned with performance accuracy including error rate and overshoot rate, it was found that: the younger subjects were generally significantly more accurate than were the older subjects; the difference between the accuracy of males and that of females was not significant; and the difference between Type A and Type B cardiovascular behavioral profile subjects was also not significant. In relation to the seventh, eighth, and ninth hypotheses, which are concerned with reactions of subjects to committing an error, it was found that following a response error: older subjects did not slow their reaction times significantly more than did younger subjects; females did not slow their reaction times significantly more than did the males; and Type A subjects did not slow their reaction times siginificantly more than did the Type B cardiovascular behavioral profile subjects.

Within the limitations of this study, the following conclusions could also be made with respect to motor performance by an adult population :

(1) Practice resulted in an improvement in measures of performance speed and accuracy for all subjects, especially for those over 75 years of age; and especially for females.

(2) All groups significantly modified their response speed from the first to the fifth quintile, i.e., the more familiar the between-target movement was, the faster was the response.

(3) The increase in correct reaction times with decreasing directional probability was not significantly disproportionate for subjects older than 70 years of age, beyond that observed for subjects younger than 70 years of age.

(4) Identifying subjects on the basis of chronological age and gender provided a more accurate representation of the subject's performance capabilities than categorization on either dimension alone.

(5) The performance of subjects seventy years of age and older was consistent with those subjects who sacrifice speed for the sake of accuracy.

(6) The speed and the accuracy of the performance of subjects still very active in community service was superior to that of their more sedate same-sex contemporaries.

Recommendations

Based upon literature reviewed pertaining to cardiovascular dysfunction, there was evidence to suggest that a significant difference in both performance speed and accuracy would exist between the two cardiovascular behavioral profile groups. Since the present study could not support this prediction it would seem that more research aimed at isolating the origins of, and the onset of the influence of the alleged cardiovascular behavioral profile on motor performance is necessary.

Both the review of literature and the results of this study suggested that the anxiety perceived by, or experienced by seniors in testing situations be recorded, and in the best interests of the subject, fears be alleviated. It might also be of interest to future investigations to record and compare the strategies employed by each of the subjects in performing complex motor tasks, in particular, those strategies used by each gender, and/or by each age group. Was speed sacrificed for accuracy? or vice-versa?

In addition, based upon the results of this study it would be interesting to compare the motor performance of those who have active lifestyles, involving continued decision-making with those who are more sedate and restricted in their decision-making. An extrapolation of this point would involve a comparison of the motor performance of persons who live independently with those who live in facilities catering to the needs of the elderly. Although not possible within the confines of the present study, these latter comparisons might be an interesting examination into the effects of withdrawal from daily decision-making on overall motor performance. It is also recommended that any research investigating the effects of ontogenetic change on performance include equal numbers of both males and females of the same age, and take into account the effect of practise, for example by using a repeated measures design. Otherwise, serious misrepresentation of the true potential of the adult population may result. This in turn would not only be detrimental to the validity of the investigation, but invariably disparaging to the image of the elderly as well.

Limitations

With any study there are limitations to the generalizations that can be made following the presentation of the results. Having categorized the subjects by age, gender, and by cardiovascular behavioral profile, the resultant cell sizes were small. Even though the tracometer yields an abundance of information for each subject per trial, perhaps had time permitted and there been more subjects per group some of the findings might have been more statistically significant. Recall that in the present study no direct analysis was employed to assess the effects of task complexity and of practise on adaptations to reaction times following a response error. In light of the pervading influence that these two variables demonstrated on performance measures cited throughout this thesis, the incorporation of a design accomodating this assessment might have proven useful. It must also be remembered that only healthy seniors participated in this study, consequently the application of these results to persons suffering from varying degrees of cardiovascular, cerebrovascular, or biomechanical dysfunction would be misleading.

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APPENDIX A

DISTRIBUTIONS OF PERFORMANCE MEASURES

Aging and Error Responses 1983/85

Factor 1 gender all. 2 levels
Factor 2 age levels
1 2 3 4 5 6
Factor 3 type 1 all 2 levels
Factor 4 subject all 5 levels
Factor 5 block all 4 levels
Factor 6 trial all 2 levels
All movements included

Reaction times

Millisecs		N
101	150	1437
151	200	1794
201	250	2095
251	300	6667
301	350	11686
351	400	14573
401	450	13785
451	500	10966
501	550	8024
551	600	5628
601	650	3809
651	700	2591
701	750	1246
751	800	793
801	850	914
851	900	684
901	950	540
951	1000	472
1001	1050	421
1051	1100	336
1101	1150	296
1151	1200	244
1201	1250	190
1251	1300	179
1301	1350	150
1351	1400	140
1401	1450	118
1451	1500	100
1501	1550	92
1551	1600	71
1601	>	865

3000 6000 9000 12000 1500

Total	91729.	Minimum	101	Standard deviation	299.69
Missing data	521	Maximum	10745	Skewness	10.53
Excluded data	3750	Mean	477.	Kurtosis	301.57
Histogram scale	300	Median	324		

Inclusion criteria 101 and 16000

Aging and Error Responses 1980/85

Factor 1 gender all 2 levels
Factor 2 age levels
1 / 2 3 4 5 6
Factor 3 type all 2 levels
Factor 4 subject all 5 levels
Factor 5 block all 4 levels
Factor 6 trial all 2 levels
All movements included

Reaction times for correct responses

Millisecs		N
101	150	837
151	200	1178
201	250	2499
251	300	5742
301	250	9720
351	400	11689
401	450	10836
451	500	8675
501	550	[illegible]
551	400	4731
601	650	3294
651	700	2734
701	750	1077
751	800	694
801	250	748
851	900	580
901	950	446
951	1000	386
1001	1050	341
1051	1100	274
1101	1150	238
1151	1200	190
1201	1250	138
1251	1200	142
1301	1350	117
1351	1400	105
1401	1450	91
1451	1500	76
1501		486

2500 5000 7500 10000 12500

Total	74326	Minimum	101	Standard deviation	290.94
Missing data	36	Maximum	13024	Skewness	10.45
Excluded data	2288	Mean	479	Kurtosis	307.31
Histogram scale	250	Median	386		

Inclusion criteria: 101 and 16000
Error criterion: 15

Aging and Error Responses 1983/85

```
Factor 1   gender     all   2 levels
Factor 2   age        levels
                        1   2   3   4   5   6
Factor 3   type       all   2 levels
Factor 4   subject    all   5 levels
Factor 5   block      all   4 levels
Factor 6   trial      all   2 levels
All movements included
```

Reaction times for error responses ...

Millisecs		N	
101	150	600	******
151	200	616	*******
201	250	576	******
251	300	944	**********
301	350	1960	********************
351	400	2880	*****************************
401	450	2947	******************************
451	500	2093	*********************
501	550	1397	**************
551	600	897	*********
601	650	515	******
651	700	347	****
701	750	167	**
751	800	99	*
801	850	166	**
851	900	104	**
901	950	97	*
951	1000	86	*
1001	1050	80	*
1051	1100	62	*
1101	1150	58	*
1151	1200	54	*
1201	1250	38	*
1251	1300	37	*
1301	1350	31	*
1351	1400	32	*
1401	1450	27	*
1451	1500	24	*
1501	1550	18	*
1551	1600	17	*
1601	>	207	***

1000 2000 3000 4000 500

Total	17198	Minimum	101	Standard deviation	335.43
Missing data	102	Maximum	13745	Skewness	10.51
Excluded data	1461	Mean	468.	Kurtosis	271.16
Histogram scale	100	Median	316		

Inclusion criteria 101 and 16000
Error criterion: 15

Aging and Error Responses 1983/85

Factor 1	gender	all	2 levels
Factor 2	age	levels 1 2 3 4 5 6	
Factor 3	type	all	2 levels
Factor 4	subject	all	5 levels
Factor 5	block	all	4 levels
Factor 6	trial	all	2 levels

All movements included

Movement times

Millisecs		N	
1	250	56	*
251	500	4892	**********
501	750	14408	*****************************
751	1000	20908	**
1001	1250	17811	************************************
1251	1500	12852	**************************
1501	1750	8181	*****************
1751	2000	5126	***********
2001	2250	3266	*******
2251	2500	2144	*****
2501	2750	1495	***
2751	3000	1012	***
3001	3250	739	**
3251	3500	574	**
3501	3750	412	*
3751	4000	352	*
4001	4250	265	*
4251	4500	213	*
4501	4750	191	*
4751	5000	160	*
5001	5250	118	*
5251	5500	129	*
5501	5750	109	*
5751	6000	84	*
6001	6250	63	*
6251	6500	62	*
6501	6750	44	*
6751	7000	40	*
7001	7250	34	*
7251	7500	26	*
7501	>	326	*

5000 10000 15000 20000 2500

Total	98603.	Minimum	68	Standard deviation	1031.55
Missing data	297	Maximum	83199	Skewness	12.03
Excluded data	0	Mean	1628.	Kurtosis	347.70
Histogram scale	500	Median	1312		

Aging and Error Responses 1983/85

```
Factor 1   gender     all   2 levels
Factor 2   age        levels
                        1    2    3    4    5    6
Factor 3   type       all   2 levels
Factor 4   subject    all   5 levels
Factor 5   block      all   4 levels
Factor 6   trial      all   2 levels
All movements included

   Movement times for responses without overshoot

   Milliseconds           N

      1   200      27   *
    201   400    1641   *****
    401   600    6708   *****************
    601   800   12549   ********************************
    801  1000   14274   ************************************
   1001  1200   11960   ******************************
   1201  1400    8882   **********************
   1401  1600    6208   ****************
   1601  1800    4055   ***********
   1801  2000    2078   ******
   2001  2200    1532   ****
   2201  2400    1156   ***
   2401  2600     780   **
   2601  2800     566   **
   2801  3000     379   *
   3001  3200     287   *
   3201  3400     312   *
   3401  3600     161   *
   3601  3800     117   *
   3801  4000      75   *
   4001  4200      81   *
   4201  4400      74   *
   4401  4600      61   *
   4601  4800      45   *
   4801  5000      37   *
   5001  5200      24   *
   5201  5400      24   *
   5401  5600      20   *
   5601  5800      24   *
   5801  6000      18   *
   6001   >       142   *
                         .......|.........|.........|.........|.........
                              4000      8000     12000     16000     20000

     Total            75021.    Minimum      182     Standard deviation   701.92
   Missing data           3     Maximum    25163     Skewness               5.17
   Exploded data          1     Mean        1178.    Kurtosis             102.31
   Histogram scale      400     Median      1035

   Inclusion criteria:   101 and 400000
   Overshoot criterion:   51
```

Aging and Error Responses [illegible]

```
Factor 1   gender      all    2 levels
Factor 2   age         levels
                          1    2    3    4    5    6
Factor 3   type        all    2 levels
Factor 4   subject     all    5 levels
Factor 5   block       all    4 levels
Factor 6   trial       all    2 levels
All movements included
```

Movement times for responses with overshoot

```
  Millisecs          N
     1  200          0
   201  400         21   *
   401  600        394   ****
   601  800       1657   *****************
   801 1000       2362   ************************
  1001 1200       2799   ****************************
  1201 1400       2512   **************************
  1401 1600       2093   *********************
  1601 1800       1699   *****************
  1801 2000       1274   *************
  2001 2200       1027   ***********
  2201 2400        795   ********
  2401 2600        625   *******
  2601 2800        491   *****
  2801 3000        400   ****
  3001 3200        306   ****
  3201 3400        278   ***
  3401 3600        253   ***
  3601 3800        187   **
  3801 4000        181   **
  4001 4200        131   **
  4201 4400        110   **
  4401 4600        107   **
  4601 4800         92   *
  4801 5000         87   *
  5001 5200         67   *
  5201 5400         88   *
  5401 5600         74   *
  5601 5800         52   *
  5801 6000         54   *
  6001  >          452   *****
                         ........|.........|.........|.........|.........
                               1000      2000      3000      4000      5000

        Total      20581.    Minimum     263     Standard deviation  1662.72
 Missing data          5     Maximum   83199     Skewness              11.[illegible]
Excluded data          0     Mean       1876.    Kurtosis             267.46
Histogram scale      100     Median     1459

Overshoot criterion:  51
```

```
                         Aging and Error Responses          1983/85

Factor 1   gender        all    2 levels
Factor 2   age           levels
                           1    2    3    4    5    6
Factor 3   type          all    2 levels
Factor 4   subject       all    5 levels
Factor 5   block         all    4 levels
Factor 6   trial         all    2 levels
All movements included

    Total response times

      Millisecs        N

      101  300         0
      301  500        15   *
      501  700       670   **
      701  900      2312   *******
      901  1100     9196   **************************
     1101  1300    14253   *****************************************
     1301  1500    14876   *******************************************
     1501  1700    12706   ************************************
     1701  1900     9956   ****************************
     1901  2100     7505   *********************
     2101  2300     5370   ***************
     2301  2500     3840   ***********
     2501  2700     2796   ********
     2701  2900     2134   ******
     2901  3100     1572   ****
     3101  3300     1269   ****
     3301  3500      997   ***
     3501  3700      770   ***
     3701  3900      616   **
     3901  4100      460   **
     4101  4300      374   **
     4301  4500      352   **
     4501  4700      270   *
     4701  4900      248   *
     4901  5100      209   *
     5101  5300      181   *
     5301  5500      139   *
     5501  5700      117   *
     5701  5900      112   *
     5901  6100       94   *
     6101  &        952   ***
                          .........I.........I.........I.........I.........
                               3500      7000      10500     14000     17500

          Total   95461     Minimum      321     Standard deviation  1146.89
   Missing data     308     Maximum    80931     Skewness               9.69
  Excluded data       0     Mean        1842     Kurtosis             404.13
Histogram scale     350     Median      1484
```

APPENDIX B

MULTIVARIATE ANALYSES OF PERFORMANCE SPEED MEASURES

Composite of the Performance Speed Measures
(Ages 55 to 74 years)

Source	Multivariate Pillais Approx. F	Univariate Derived F TRT	CRT	NO-OVMT
Age	3.27****	12.27****	6.47****	9.81****
Gender	5.95****	16.01****	4.67****	13.89****
Type	0.91	0.03	1.13	0.23
Task Complexity	N.A.	N.A.	250.46****	532.22****
Block (of trials)	12.93****	80.29****	70.47****	40.95****
Age X Gender	1.09	0.97	0.84	0.99
Age X Type	0.64	1.00	1.24	0.91
Age X Complx	N.A.	N.A.	0.44	2.93****
Age X Block	1.36	1.36	1.32	0.66
Gender X Type	1.46	1.16	0.74	0.00
Gender X Complx	N.A.	N.A.	0.90	2.56
Gender X Block	3.17**	3.28**	3.37**	3.89**
Type X Complx	N.A.	N.A.	0.13	0.23
Type X Block	0.89	0.13	0.15	1.22
Complx X Block	N.A.	N.A.	3.00****	8.58****
Age X Gen X Type	0.65	0.40	0.33	0.10
Age X Gen X Complx	N.A.	N.A.	0.78	0.93
Age X Gen X Blk	1.44	1.71	1.37	3.15***
Age X Typ X Complx	N.A.	N.A.	0.85	0.48
Age X Typ X Blk	0.78	1.47	1.45	0.63
Gen X Typ X Complx	N.A.	N.A.	0.11	0.46
Gen X Typ X Blk	0.82	0.23	0.28	0.41
Age X Complx X Blk	N.A.	N.A.	0.82	0.50
Gen X Complx X Blk	N.A.	N.A.	0.52	1.33
Typ X Complx X Blk	N.A.	N.A.	0.72	1.26
Age X Gen X Typ X Complx	N.A.	N.A.	1.15	0.70
Age X Gen X Typ X Blk	0.99	1.55	0.69	0.30
Age X Gen X Complx X Blk	N.A.	N.A.	1.48	1.59
Age X Typ X Complx X Blk	N.A.	N.A.	1.13	1.14
Gen X Typ X Complx X Blk	N.A.	N.A.	0.86	0.82
Age X Gen X Typ X Complx X Blk	N.A.	N.A.	1.20	0.54

Note:
TRT = Total Response Time
CRT = Correct Reaction Time
NO-OVMT = Non-Overshoot Movement Time
Type = Cardiovascular Behavioral Profile
Task Complexity = depicts effect of Directional Probability on CRT; and of Movement Amplitude on NO-OVMT
N.A. = Analysis not applicable

Interaction Abbreviations:
Gen = Gender; Typ = Type (as above);
Complx = Task Complexity (as above); Blk = Block of trials
Significance Level: * = $p<.05$ ** = $p<.025$
*** = $p<.01$ **** = $p<.001$

Composite of the Performance Speed Measures
(Ages 55 to 84 years)

Source	Multivariate Pillais Approx. F	Univariate Derived F TRT	CRT	NO-OVMT
Age	1.94**	6.45****	4.78****	4.86****
Gender	2.61*	6.31**	2.68	6.92***
Task Complexity	N.A	N.A.	195.46****	526.28****
Block (of trials)	10.01	93.84****	87.02****	21.57****
Age X Gender	0.56	0.41	0.68	0.22
Age X Complx	N.A.	N.A.	0.43	2.68****
Age X Block	1.05	3.00	2.53	0.81
Gender X Complx	N.A.	N.A.	0.54	2.46
Gender X Block	1.02	4.15****	5.17****	0.54
Complx X Block	N.A.	N.A.	3.16****	4.46****
Age X Gen X Complx	N.A.	N.A.	0.80	0.76
Age X Gen X Blk	0.89	0.41	1.41	1.16
Age X Complx X Blk	N.A.	N.A.	1.14	1.09
Gen X Complx X Blk	N.A.	N.A.	1.54	0.63
Age X Gen X Complx X Blk	N.A.	N.A.	1.20	1.23

Note:
TRT = Total Response Time
CRT = Correct Reaction Time
NO-OVMT = Non-Overshoot Movement Time
Task Complexity = depicts effect of Directional Probability on CRT; and of Movement Amplitude on NO-OVMT
N.A. = Analysis not applicable
Interaction Abbreviations:
Gen = Gender; Complx = Task Complexity (as above);
Blk = Block of trials
Significance Level: * = p<.05 ** = p<.025
*** = p<.01 **** = p<.001

APPENDIX C

UNIVARIATE ANALYSES OF TOTAL RESPONSE TIME MEASURES

Total Response Time Scores

Source	Ages 55-74 F	df	Ages 55-84 F	df
Between- Subjects				
Age	12.25****	3	8.68****	5
Gender	15.98****	1	10.11****	1
Type	0.04	1	N.A.	
Age X Gender	0.97	3	0.21	5
Age X Type	1.01	3	N.A.	
Gender X Type	1.19	1	N.A.	
Age X Gender X Type	0.41	3	N.A.	
residual		64		48
Within-Subjects				
Block (of trials)	80.29****	3	93.84 ****	3
Age X Block	1.36	9	3.00 **	15
Gender X Block	3.28**	3	4.15 **	3
Type X Block	0.13	3	N.A.	
Age X Gender X Block	1.71	9	0.41	15
Age X Type X Block	1.47	9	N.A.	
Gender X Type X Block	0.23	3	N.A.	
Age X Gen X Typ X Blk	1.55	9	N.A.	
residual		192		144
Total		319		239

Note:
N.A. = Analysis not applicable
Interaction Abbreviation:
Gen = Gender
Typ = Type
Blk = Block
Significance Level: * = p<.05 ** = p<.025
*** = p<.01 **** = p<.001

Total Response Time By Quintile

Source	Ages 55-74 F	df	Ages 55-84 F	df
Between-Subjects				
Age	12.24****	3	8.68****	5
Gender	15.98****	1	10.11****	1
Type	0.04	1	N.A.	
Age X Gender	0.97	3	0.21	5
Age X Type	1.01	3	N.A.	
Gender X Type	1.19	1	N.A.	
Age X Gender X Type	0.41	3	N.A.	
residual		64		48
Within-Subjects				
Block (of Trials)	80.22****	3	93.94****	3
Age X Block	1.35	9	3.00****	15
Gender X Block	3.26***	3	4.13****	3
Type X Block	0.13	3	N.A.	
Age X Gender X Block	1.71	9	0.41	15
Age X Type X Block	1.46	9	N.A.	
Gender X Type X Block	0.22	3	N.A.	
Age X Gen X Typ X Blk	1.55	9	N.A.	
residual		192		144
Quintile	3.44****	4	8.76****	4
Age X Quintile	1.50	12	1.09	20
Gender X Quintile	1.95	4	0.36	4
Type X Quintile	0.99	4	N.A.	
Age X Gen X Quin	1.39	12	0.73	20
Age X Typ X Quin	0.97	12	N.A.	
Gen X Typ X Quin	1.63	4	N.A.	
Age X Gen X Typ X Quin	1.58	12	N.A.	
residual		256		192
Block X Quintile	10.46****	12	7.77****	12
Age X Blk X Quin	1.04	36	1.06	60
Gen X Blk X Quin	1.58	12	1.05	12
Typ X Blk X Quin	0.51	12	N.A.	
Age X Gen X Blk X Quin	1.26	36	0.71	60
Age X Typ X Blk X Quin	1.29	36	N.A.	
Gen X Typ X Blk X Quin	0.78	12	N.A.	
Age X Gen X Typ X Blk X Quin	0.72	36	N.A.	
residual		768		576
Total		1599		1199

Note:
N.A. = Analysis not applicable
Interaction Abbreviations:
Gen = Gender
Typ = Type
Blk = Block
Quin = Quintile
Significance Level: * = p<.05 ** = p<.025
*** = p<.01 **** = p<.001

APPENDIX D

UNIVARIATE ANALYSES OF CORRECT REACTION TIME MEASURES

Correct Reaction Time Measures for Three Levels of Directional Probability (1.00, 0.75, 0.50)

Source	Ages 55-74 F	df	Ages 55-84 F	df
Between-Subjects				
Age	6.47****	3	9.64****	5
Gender	4.67***	1	3.41	1
Type	1.12	1	N.A.	
Age X Gender	0.84	3	1.45	5
Age X Type	1.24	3	N.A.	
Gender X Type	0.74	1	N.A.	
Age X Gender X Type	0.33	3	N.A.	
residual		64		48
Within-Subjects				
Block (of trials)	70.47****	3	87.02****	3
Age X Block	1.32	9	2.53****	15
Gender X Block	3.33***	3	5.17****	3
Type X Block	0.15	3	N.A.	
Age X Gen X Blk	1.37	9	1.41	15
Age X Type X Blk	1.39	9	N.A.	
Gen X Typ X Blk	0.28	3	N.A.	
Age X Gen X Typ X Block	0.69	9	N.A.	
residual		192		144
Probability	250.46****	2	195.46****	2
Age X Prob	0.44	6	0.43	10
Gender X Prob	0.90	2	0.54	2
Type X Prob	0.13	2	N.A.	
Age X Gen X Prob	0.78	6	0.80	10
Age X Typ X Prob	0.85	6	N.A.	
Gen X Typ X Prob	0.11	2	N.A.	
Age X Gen X Typ X Prob	1.15	6	N.A.	
residual		128		96
Block X Prob	3.00****	6	3.16****	6
Age X Blk X Prob	0.82	18	1.14	30
Gen X Blk X Prob	0.52	6	1.54	6
Typ X Blk X Prob	0.72	6	N.A.	
Age X Gen X Blk X Prob	1.48	18	1.20	30
Age X Typ X Blk X Prob	1.13	18	N.A.	
Gen X Typ X Blk X Prob	0.86	6	N.A.	
Age X Gen X Typ X Blk X Prob	1.20	18	N.A.	
residual		384		288
Total		959		719

Note:
N.A. = Analysis not applicable
Probability = Directional Probability
Interaction Abbreviations:
Gen = Gender
Typ = Type
Blk = Block
Prob = Directional Probability
Significance Level: * = p<.05 ** = p<.025
*** = p<.01 **** = p<.001

Table 22

Correct Reaction Times (msec) For Gender X Block X Directional Probability

Block	Gender	1.00	0.75	0.50	0.25
		Directional Probability			
1	Female	577	615	633	607
	(SD)	37.4	28.7	32.5	28.1
	Male	464	517	517	521
	(SD)	19.5	18.2	16.0	14.2
2	Female	484	544	569	541
	(SD)	30.6	27.7	28.4	26.4
	Male	420	471	479	488
	(SD)	17.5	14.8	14.8	15.1
3	Female	459	521	551	568
	(SD)	31.0	28.4	30.9	36.8
	Male	392	447	469	490
	(SD)	16.1	15.2	15.3	14.5
4	Female	440	512	534	558
	(SD)	30.3	32.2	28.7	27.5
	Male	384	447	459	474
	(SD)	15.9	16.8	14.5	15.2

Note: (SD) = Standard Deviation

APPENDIX E

UNIVARIATE ANALYSES FOR NON-OVERSHOOT MOVEMENT TIME

Non-Overshoot Movement Time for four Levels of Movement Amplitude (41, 82, 123, 164 mm)

Source	Ages 55-74 F	Ages 55-74 df	Ages 55-84 F	Ages 55-84 df
Between-Subject				
Age	9.27****	3	5.43****	5
Gender	12.46****	1	8.30****	1
Type	0.15	1	N.A.	
Age X Gender	0.97	3	0.22	5
Age X Type	0.82	3	N.A.	
Gender X Type	0.00	1	N.A.	
Age X Gen X Typ	0.14	3	N.A.	
residual		64		48
Within-Subjects				
Block (of trials)	40.95****	3	21.57****	3
Age X Block	0.66	9	0.81	15
Gender X Block	3.89***	3	0.54	3
Type X Block	1.22	3	N.A.	
Age X Gen X Blk	3.15	9	1.16	15
Age X Typ X Blk	0.63	9	N.A.	
Gen X Typ X Blk	0.41	3	N.A.	
Age X Gen X Typ X Blk	0.30	9	N.A.	
residual		192		144
Distance	532.22****	3	526.28****	3
Age X Dist	2.93****	9	1.98***	15
Gender X Dist	2.56	3	2.26	3
Type X Dist	0.23	3	N.A.	
Age X Gen X Dist	0.93	9	0.76	15
Age X Typ X Dist	0.48	9	N.A.	
Gen X Typ X Dist	0.46	3	N.A.	
Age X Gen X Typ X Dist	0.70	9	N.A.	
residual		192		144
Block X Dist	8.58****	9	4.46****	9
Age X Blk X Dist	0.50	27	1.09	45
Gen X Blk X Dist	1.33	9	0.63	9
Typ X Blk X Dist	1.26	9	N.A.	
Age X Gen X Blk X Dist	1.59	27	1.23	45
Age X Typ X Blk X Dist	1.14	27	N.A.	
Gen X Typ X Blk X Dist	0.82	9	N.A.	
Age X Gen X Typ X Blk X Dist	0.54	27	N.A.	
residual		576		432
Total		1279		959

Note:
N.A. = Analysis not applicable
Distance = Target Distance
Interaction Abbreviations:
Gen = Gender
Typ = Type
Blk = Block
Dist = Target Distance
Significance Level: * = $p<.05$ ** = $p<.025$
*** = $p<.01$ **** = $p<.001$

APPENDIX F

PERCENTAGE OF ERRORS FOR BLOCK (OF TRIALS) X DIRECTIONAL PROBABILITY

Table 23

Percentage of Errors for Block (of trials) X Directional Probability

Block		Directional Probability 1.00	0.75	0.50	0.25
1	Female	7.0	21.9	40.7	48.4
	(SD)	1.0	1.6	1.8	2.5
	Male	4.8	22.8	41.3	46.3
	(SD)	0.9	1.4	1.8	2.5
2	Female	4.8	18.1	38.6	48.5
	(SD)	0.7	1.1	1.8	2.8
	Male	4.8	18.3	37.9	48.0
	(SD)	0.8	1.2	1.8	2.4
3	Female	4.6	14.6	34.9	50.1
	(SD)	0.8	1.0	1.8	2.6
	Male	2.9	15.8	35.4	53.8
	(SD)	0.5	1.2	1.7	2.7
4	Female	5.5	13.9	32.8	49.6
	(SD)	1.0	1.0	1.4	2.5
	Male	3.8	13.5	35.4	53.9
	(SD)	0.8	1.1	1.6	2.7

Note: (SD) = Standard Deviation

APPENDIX G

CORRECT REACTION TIME SCORES FOLLOWING A RESPONSE ERROR

Summary of the ANOVA for Correct Reaction Time Following An Error Response

Source	Directional Probability 1.00	df	0.75	df
Between-Subjects				
Age	5.91****	3	6.09****	3
Gender	3.39	1	3.63	1
Type	0.91	1	1.20	1
Age X Gender	0.84	3	1.00	3
Age X Type	1.58	3	1.08	3
Gender X Type	0.57	1	0.80	1
Age X Gen X Typ	0.24	3	0.34	3
residual		64		64
Within-Subjects				
Block (of trials)	73.60****	3	76.93****	3
Age X Block	1.10	9	0.53	15
Gender X Block	2.18	3	0.29	3
Type X Block	0.46	3	0.20	3
Age X Gen X Blk	1.36	9	1.37	15
Age X Typ X Blk	0.86	9	1.68	9
Gen X Typ X Blk	1.48	3	0.02	3
Age X Gen X Typ X Blk	0.62	9	0.27	9
residual		192		192
Previous	0.33	1	3.49	1
Age X Prev	0.48	3	0.13	3
Gender X Prev	1.16	1	0.46	1
Type X Prev	0.19	1	0.92	1
Age X Gen X Prev	1.29	3	0.23	3
Age X Typ X Prev	0.95	3	2.08	3
Gen X Typ X Prev	0.39	1	0.35	1
Age X Gen X Typ X Prev	0.80	3	1.60	3
residual		64		64
Block X Prev	1.39	3	0.16	3
Age X Blk X Prev	1.07	9	0.94	9
Gen X Blk X Prev	2.23	3	0.01	3
Typ X Blk X Prev	1.13	3	0.45	3
Age X Gen X Blk X Prev	1.33	9	0.89	9
Age X Typ X Blk X Prev	1.02	9	0.73	9
Gen X Typ X Blk X Prev	1.62	3	1.61	3
Age X Gen X Typ X Blk X Prev	1.60	9	1.80	9
residual		192		192
Total		639		639

Note:
N.A. = Analysis not applicable
Previous = Previous Response Correctness
Interaction Abbreviations:
Gen = Gender
Typ = Type
Blk = Block
Prev = Previous Response Correctness
Significance Level: * = p<.05 ** = p<.025
*** = p<.01 **** = p<.001

APPENDIX H

TRACOMETER TEST RECORD SHEET

STRESSALYSER TEST RECORD

CASSETTE	No. SIDE
	:

Use a new Record Sheet for each side of the Cassette.

EXPERIMENT	
CONTROL UNIT	

TEST INFORMATION							DECODING INFORMATION						
RUN	TEST	DATE	TIME of DAY	PRO-GRAM	SUBJECT	TOTAL TIME	TAPE COUNT	DEC; No.	DATA SUM	EDI; No.	CORRECTIONS	FACTOR LEVELS 1:2:3:4:5:6	LAB; No.
Make an entry each time START is pressed, whether or not the run is completed													
1												: : : : :	
2												: : : : :	
3												: : : : :	
4												: : : : :	
5												: : : : :	
6												: : : : :	
7												: : : : :	
8												: : : : :	
Check amount of unused tape before continuing													
9												: : : : :	
10												: : : : :	
11												: : : : :	
12												: : : : :	

EXPERIMENTER	DECODER	EDITOR	LABELLER

REMARKS

C.S. and H.E. - I (Revised 11 April, 1979)